DO NOT REMOVE THIS COPY

[redacted]

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
Exhibit E, Para. 7.3	023	LEM	NAS 9-1100	1/14/63

CLASSIFICATION CHANGE

Type II

To UNCLASSIFIED

By authority of GDS - EO 11652

Changed by L. Shirley Date 12/3/72

Classified Document Master Control Station, NASA
Scientific and Technical Information Facility

Primary No. 760

REPORT

NO. LPR-550-6 DATE: 1 August 1964

QUARTERLY RELIABILITY STATUS REPORT [U]

CODE 26512

D. F. Smith
PREPARED BY:
LEM Reliability Section

George C. Wiesinger
CHECKED BY:
George C. Wiesinger

C W Rathke
APPROVED BY:
C. W. Rathke/A. B. Whitkaer

REVISIONS

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS

[redacted]

~~This document contains information affecting the national defense of the United States, within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.~~

DO NOT REMOVE THIS COPY

~~GROUP 4. DOWNGRADED AT 3 YEAR INTERVALS; DECLASSIFIED AFTER 12 YEARS.~~

[redacted]

TABLE OF CONTENTS

ABSTRACT

This Quarterly Reliability Status Report is submitted in fulfillment of the requirements of Paragraph 7.3 of Reference (a), and is the sixth in a series of reports to be submitted as part of the Reliability Plan.

1.0 INTRODUCTION AND SUMMARY

1.1 Introduction

Updated estimates of LEM mission success and crew safety have not been made this quarter primarily because of several configuration changes under study. Reliability analyses of these configuration changes have been performed and reported in the individual subsystem section.

A review of the fourth and fifth quarterly report was held with MSC during the latter part of this quarter. A format and groundrules for future reports was agreed to at this meeting. It was decided that the new format would be used starting with the seventh quarterly report since incorporating these changes in this report would have resulted in a considerable delay in its release.

1.2 Summary

During this quarter the major effort in Systems and Subsystems Reliability Group was in the area of weight-reliability and configuration trade-off studies. These studies have included micrometeorite shielding, the helium pressurization of the ascent and descent propulsion, electrical power system generation and distribution and the over-all Navigation and Guidance function. Reliability analyses of all other areas has also been continuing. In light of the fact that GAEC and NASA/MSC are examining alternate approaches for increasing the Control Weight, weight-reliability trade-off studies will continue during the next quarter.

The Failure Mode and Effect Analysis was begun during this quarter and a schedule of milestone dates submitted to MSC. The approach and the schedule for performing the over-all LEM FMEA and the integration of vendor FMEA's is presented in Section 3.

1.2 Summary (continued)

Continuous effort is being devoted to the reliability and maintainability aspects of new and revised specification requirements, proposal evaluation and review and analyses of general subcontractor documentation. These are presented in Sections 4 and 5.

Reliability Assurance test planning continued during this quarter. This effort reported in Section 5 has been continued in all subsystem areas and LTA's 1 through 10.

Revisions and updating of the Acceptable Parts Lists and Application Guide, LED-550-25, continued. Revised deratings for all transistors and semiconductor diodes have been completed.

Maintainability analyses have been started in the propulsion, reaction control, communications, flight controls and environmental control subsystems. These have included design prelaunch checkout operations and GSE consideration.

The major effort on LEM GSE during this quarter has been in developing a reliability program for GSE, the establishment of specification and vendor requirements format for reliability and maintainability requirements, and analyses of GSE common-usage reliability requirements. This effort is presented in Section 6.

The ARINC Reliability Training Course was completed during this quarter and was considered very successful.

2.0 RELIABILITY MANAGEMENT

During this period the LEM Reliability Program has been implemented to comply with the NASA Reliability Publication NPC-250-1. An errata and revisions to LPL-550-1A, the Grumman Reliability Plan of 30 April 1964, has been submitted on 26 June 1964.

A review of the fourth and fifth Quarterly Reliability Status Report was held with MSC during the latter part of this quarter. The format and guidelines for further quarterlies was agreed upon. These changes will be incorporated in the seventh quarterly report. Specifically this section, Reliability Management, will present the status of the Reliability Program in a form such that can be collated with NPC-250-1. This section will include, among other things, relationship between GAEC and its subcontractors, schedules and problem areas, and reliability trend indicators.

3.0 SYSTEMS ANALYSIS

3.1 General

During this quarter, the major system reliability analysis effort was spent in the continuation of weight-reliability trade-off studies, and configuration analyses. This effort has been directed toward the optimization of mission success and crew safety within the over-all LEM control weight. The results of the weight-reliability trade-off study for meteoroid shielding is presented in Section 3.3, and the effort being conducted to trade-off weight and reliability in the flight measurements area reported in Section 3.4. Work has continued in developing the reliability paths for each subsystem and the over-all system for estimating mission success and crew safety. This effort is reported in Section 3.5. During this quarter, the LEM Failure Mode and Effect Analysis has been started. The approach to be taken and a schedule of milestones is reported in Section 3.6. Section 3.7 discusses the present status of the LEM Reliability Control Computer Program.

3.2 Reliability Evaluation Mission Profile

The reliability mission profile is designed to provide a basic mission time line for reliability estimation by both LEM subcontractors and Grumman. This profile represents a standard time line which is most representative of flyable LEM missions. While this profile will be updated periodically, it is not intended that it will be changed for every minute mission time change. It should be noted that profiles, such as Critical Design and Weight Reporting Missions, have been developed by various LEM groups in order to best describe their particular area of concentration. In the same context, this mission profile describes a typical LEM mission to be used in all reliability analysis.

Table 3.1, Mission Profile for Reliability Estimates, separates the LEM mission into ten (10) major phases and partitions it into boost and non-boost times. Boost time being defined as whenever a major propulsion unit is operating and subjecting the LEM to added environmental stresses. The K factors for Non-Boost, Boost, Non-Boost Non-Operative, and Boost Non-Operative represent multiplication factors on the basic failure rates to account for the various environmental and operational states. This reliability profile is being implemented in all design control specifications.

TABLE 3.1

MISSION PROFILE FOR RELIABILITY ESTIMATES

Nominal Phase	Main Phase	Mission Times: Non-Boost Hours	Mission Times: Boost Hours	Equipment Operating Time Profile: Non-Boost Oper. K=1.0	Boost Oper. K=10	Non-Boost Non-Oper. K=.001	Boost Non-Oper. K=.01
	Prelaunch	10.0					
	Earth Launch		0.197				
	Earth Orbit Through Transposition	3.8	0.087				
	Continued Translunar Trip Through Lunar Orbit Injection	72.2	0.09				
	Coast In Lunar Orbit (LEM Checkout)	4.0 (1.85)					
1	Total Pre-separation	90.0	0.374				
2	LEM Separation To Insertion	0.478					
3	Insertion And Hohmann Transfer Orbit	0.968	0.002				
4	Powered Descent From Pericynthion To Hover		0.133				
5	Hover To Touchdown		0.050				
	Post Landing Chkt.	1.25					
	Exploration	1.083					
	Prelaunch Preparation	1.667					
6	Total Lunar Stay For Mission Success Estimate	4.00					
6A	Additional Lunar Stay For Crew Safety Estimate	20.0					
7	Powered Ascent And Injection		0.093				
8	Transfer Coast	0.7					
9	Rendezvous (5 Nautical Miles To 500 Feet)	0.167					
10	Docking (500 Feet To Contact)	0.25					

3.3 Weight-Reliability Trade-Off Study (Meteoroid)

During this quarter, the Phase II effort of the LEM weight-reliability study was completed and reported in LED-550-29.

The objective of this phase of the study was to determine the relationship between meteoroid shielding and over-all LEM weight-reliability constraints. The purpose of the study was to recommend how much weight in meteoroid shielding, if any, should be added to the vehicle and where it should be allocated. The meteoroid environment and penetration mechanics model utilized in the study was developed and supplied by NASA-MSC. The above referenced report contains the details of the study, but the following conclusions and recommendations describe the most important results of the study.

1. Major increases in mission success and crew safety can be obtained for an additional 160 to 250 pounds of separation weight. For the meteoroid environment only, 160 pounds of separation weight increases mission success from 0.09 to .893 and crew safety from 0.52 to .973. When combined with the inherent reliability of the LEM vehicle, the estimates are 0.822 and 0.963 for mission success and crew safety, respectively.

2. About 250 pounds of separation weight must be allocated for shielding before it would pay to allocate additional weight to increase the reliabilities of individual subsystems. The LEM system parameters of weight and reliability are optimally traded-off for total vehicle weight increases ranging from 160 to 250 pounds.

3. The optimum allocation of dry weights for an additional 160 pounds separation weight is 30 pounds in ascent stage and 16 pounds in the descent stage. This weight should be spread so as to add additional shielding to those surface areas of the total vehicle having the greatest effect on both mission success and crew safety and having the thinest inherent skin thicknesses (.006 inches). Thus, in the ascent stage, 23 pounds should be spread over the critical effective area and 7 pounds over the remaining non-critical areas of .006 shin thickness. The 16 pounds in the descent stage should be spread over those areas of .006 skin thickness. The detailed recommendations for each stage are listed in Table I below.

TABLE I

OPTIMUM DISTRIBUTION OF 160 POUNDS OF SEPARATION WEIGHT FOR METEOROID SHIELDING

Descent Stage Recommendation:

The addition of .006 inches of shielding to existing skin thicknesses of .006 inches in the Diagonal Panel and Diagonal Top Sections.

Dry Weight - 16 pounds Reliability Increase - M.S. = .52 to .975

Ascent Stage Recommendation:

1. The addition of .006 inches of shielding to existing skin thickness of .006 inches as noted below - weight 23 pounds.
2. The addition of .006 inches of shielding to existing skin thickness of .006 inches in all remaining non-critical areas as noted below - weight 7 pounds.

Title Of Section	Critical Vessels Affected	Total Area (sq.ft.)	Non-Critical Effective Area Of .006 Inches	Increase Thickness Inches	Increase Thickness Inches	Critical Effective Area	Inherent Skin Thickness	Increase Thickness
Nav Dome		13.4	13.4	.006	.006			
AFT Bay	SOX, GOX and Ascent H_e Pressure Tanks	104.5	34.5	.006	.006	70	.006	.007
Tank Section:	Ascent Propulsion	121	19.0	.006	.006	102	.006	.007
+Z BKHD	Fuel Tanks & RCS H_e	49.2	11.2	.006	.006	38	.006	.007
-Z BKHD	Pressure Tanks	55.4	1.4	.006	.006	54	.006	.007
TOTALS			79.5			264		

3. Dry Weight - 30 pounds

   Reliability Increase - 23 pounds in critical areas
   7 pounds in non-critical areas

   Mission Success = .186 to .916
   Crew Safety = .52 to .973

4. In order to evaluate the consequences involved in the implementation of the recommendations listed in Table I, a detailed study by Structural Analysis and Weights personnel is required. The principal input to this study will be the marked-up structural blueprints depicting the critical and non-critical effective areas described in Table I. These blueprints, together with the recommended skin thicknesses to be added in each area, should serve as a basis for the study. The results of the study should include the following points: first, the total penalty associated with the incorporation of these changes, both internal, e.g., welds, fasteners, supports, and stiffeners, etc., and external; additional skin thicknesses. Second, the effect of the changes on associated subsystems as well as the over-all feasibility of the changes; third, the associated considerations of cost and schedule.

Future efforts in the study include:

1. Continuous updating of weight and reliability estimates due to variations in vehicle design. It should be noted that rough parametric studies indicate that the basic conclusions presented in the report will not be significantly changed by minor variations in reliability and weight estimates.

2. A complete Failure Effects Analysis of all possible failures that can be caused by meteoroid penetrations. This study will result in more refined definition of the critical effective areas.

3. The results of Conclusion (4) will be incorporated in the over-all system approach.

4. Study the feasibility of repositioning critical components compared with weight increases with the external shielding approach over selective areas.

5. Investigation of the weight penalties connected with meteoroid shower activity.

6. Trade-offs in allocation of amounts of weight between subsystems and shielding.

3.4 Flight System Measurements

A study has been initiated in an effort to aid in the definition of measurements for the LEM 10 vehicle to be considered for either operational display, caution and warning panel, on-board checkout or telemetry. The basic approach of this analysis is to determine which measurement information is necessary and how they should be categorized, such that they represent the best balance between optimum system reliability achievement and total LEM weight constraints. The primary results of the study will be (1) a ranking with respect to weight-reliability-criticality of the measurements contained in the LEM 10 Basic Measurements List, (2) a listing of possible additions and deletions to this basic list, and (3) recommendations as to the optimum candidate measurements for operational dsiplay, caution and warning panel, on-board checkout and telemetry.

In order to carry out this evaluation process, the following general criteria or ground rules are assumed:

1. Functional information required by the crew for the proper operation of the spacecraft must be displayed.
2. Measurements are to be considered in the Caution and Warning category if out-of-limit values of the parameter being measured indicate the need for impending or immediate crew action.
3. On-Board Checkout should utilize existing operational, caution and warning, and telemetry measurements wherever possible. Additional measurements for On-Board Checkout must significantly contribute to an adequate level of confidence of spacecraft operation prior to critical mission phases.
4. Measurements for telemetry should be provided only if (a) they contribute either to supplying a means of failure anticipation which the limits of on-board displays or crew task loading prevents the crew from performing, or (b) if this measurement information would enable the earth to significantly participate in the major decision making processes of the crew.

3.4 Flight System Measurements (continued)

In evaluating and categorizing the flight system measurements from a reliability viewpoint, criteria 2, 3, and 4 require detailed analytical study. In order to facilitate this study, a preliminary format has been developed (Table 3.5.1) to compile, in a logical manner, the data necessary to carry out the weight-reliability-criticality trade-offs. Using the Basic LEM 10 Measurements List as a starting point, each measurement is being analyzed and classified according to the following parameters: first, the vehicle function being measure; second, probability of failure of this function prior to a critical mission phase; third, probability of failure of the means of measurements (sensor); fourth, criticality of the function being measured, i.e., essential for crew safety, etc.; fifth, physical weight of the measurement means and its associated hardware. The effect on the functions reliability can be derived from the mode and probability of failure of the measurement means and its reliability relationship to the function. The trade-off studies will begin during the next quarter as all the pertinent data is generated and collected.

3.5 Reliability Estimation

3.5.1 Path Analysis

Continued efforts in the reliability path analysis have been directed towards the completion of the study as described in the last quarterly report (Section 3.4). The major results of the study will take the form of reliability paths and feasibility factors by mission phase for each nominal subsystem configuration. These results, together with operating times, stress factors and updated equipment failure rate estimates are being stored on computer tape as they are complied. The tapes in turn will be used in the computer program for reliability estimation (see Section 3.5.2).

3.5.1 Path Analysis (continued)

The present status of the analysis is:

1. Mission Success Paths have been completed and documented for:

   a. Guidance and Control - including Navigation and Guidance, Stabilization and Control, and VHF portion of Communications (revised paths in LMO-550-319)

   b. Ascent and Descent Propulsion (LED-550-31)

   c. Reaction Control (LED-550-28), and

   d. Environmental Control and Electrical Power Generation (LED-550-30).

   The Descent Propulsion paths are a first cut at a high level equipment breakdown and a study at a lower level breakdown is in progress. The paths for ECS and EPS are integrated to describe the dependent functions of these subsystems. Additional paths are required to define the independent function of the two subsystems.

2. Feasibility factors are completed for the Guidance and Control and Ascent Propulsion paths. The feasibility factors for the other paths listed above are in progress.

Future efforts in this study will include:

1. Completion of path analysis (mission success) for the subsystems (Instrumentation, Communications, Structures, EED, etc.).

2. Completion of the abort paths (crew safety) for each subsystem for descent and lunar stay phases.

3. Integration of subsystem paths to form the total system paths.

TABLE 3.5.1

BASIC DATA FOR LEM MEASUREMENTS WEIGHT-RELIABILITY TRADE-OFF

Measurement	Weight Of Detection Means (lbs)	Function Being Measured	Probability Of Function Failure	Probability Of Meas. Means Fail.		Criticality Of Function Being Measured	Effect Of Det. Means On Funct. Being Meas.		Remarks
				False Alarm	Passive		M.S.	C.S.	

3.5.2 Computer Program

The main program is being modified in the following ways:

1. There will be an increase in the number of equipments which can be handled (from 99 to 999).
2. An option is provided for having the input data on cards or tape.

In addition, another program has been generated for the purpose of preparing tapes with reliability data for use with the main program. As a result, the main program is being further modified to incorporate changes to the data tapes (prepared by the side program) prior to the reliability calculations.

Two data tapes per set of equipments will be used. One unit will contain the equipment base failure rate, phase operating time, and phase stress factor. The other tape unit will contain conditional reliabilities (of successfully completing each phase given operation at the beginning of the phase) for each equipment.

The main program could conceivably perform the tasks of the side program allows for more efficient use of the main program in that less preparation of input data would be required and this gives rise to shorter running times for the program.

3.6 LEM Failure Mode And Effect Analysis

3.6.1 General Approach

The LEM system and subsystem Failure Mode and Effect Analysis (FMEA) will include a systematic evaluation of each subsystem in terms of its potential failures and the affects of these failures on the subsystem, the rest of the system, and the mission. The purpose of the FMEA is to highlight design and operational weaknesses (system and subsystem), if they exist, and to provide a basis for extending the current reliability paths for future use in trade-off studies.

3.6.1 General Approach (continued)

This analysis will be performed on the equipment level (e.g., IMU, DECA, RCA Propellant Controls, Ascent Propulsion Pressure Controls, etc.). The failures (both complete and degraded) of each equipment will be defined in terms of its functions. The function failure modes of each equipment will be examined by mission phase in the following basic areas:

1. Failure Cause

   Possible causes of the malfunction, if known, will be analyzed. The vendor failure effect analyses will be utilized in this area.

2. Uncompensated Effects On Subsystem And Spacecraft

   Assuming no corrective action were initiated by the crew, the effects of a malfunction will be examined on (a) the subsystem, (b) the other subsystems, and (c) the mission. In many cases, trajectories, oxygen supply, propellant supply, for example, will have to be considered.

3. Failure Detection Methods

   Existing failure detection methods, if any, will be indicated for each malfunction.

4. Compensating Provisions

   The continue or abort paths available after a malfunction will be analyzed. For both continue and abort paths, the areas considered will include: (a) the crew actions that might be necessary, (b) the effects on other subsystems (engine lifetimes, propellant available, consumable, etc.), (c) the interrelations with the CSM and GOSS, and (d) change and effects on DV and time from the nominal profile.

5. Criticality Class

   Each malfunction will be numerically ranked based on (a) the probability of occurrence, (b) time criticality, and (c) the consequence of the failure if uncompensated for.

3.6.1 General Approach (continued)

The analysis will, in addition, allow for a logical and effective integrations of FMEA's on lower levels of assembly, many of which are currently being performed by LEM subcontractors and vendors under LEM Reliability direction.

The major uses to which the FMEA will be put in consonance with the LEM contingency analysis are for evaluating (1) LEM subsystems for compatibility under various failure modes and causes, (2) compatibility between LEM and CSM under various failure conditions, (3) subsystem sizing (delta V budgets, error budget, tank sizing, power requirements, etc.), (4) instrumentation, and displays and controls, (5) engine lifetimes, (6) subsystem configurations, (7) crew task analysis, (8) defining requirements for the LTMS and FMES, and (9) flight operational rules and procedures.

3.6.2 LEM FMEA Milestone Schedule

The LEM Failure Mode and Effect Analysis (FMEA) milestone schedule has been established consistant with the major dates ofthe LEM Development Program. Failure Mode and Effect Analyses will be performed on all flight equipment and integrated into system FMEA's for Flight Test Articles (FTA's) and LEM vehicles one through ten. It should be noted that all LEM's will have essentially the same equipment configurations as the LEM 10 vehicle, with the addition of a Mission Programmer in LEM's 1, 2, and 3, and other modifications required for their individual missions. Individual subsystem milestone schedules are not included separately since they are all required to be updated on the milestone dates indicated.

Since most LEM equipment is subcontracted, equipment level FMEA's will be performed by Grumman's vendors. Grumman will perform equipment level FMEA's on those items it will design and manufacture. There is then the requirement to integrate the equipment level FMEA's into an over-all LEM system FMEA. The E's in the attached schedule indicate

3.6.2 LEM FMEA Milestone Schedule (continued)

equipment level FMEA's which require review, coordination, and direction of vendors, and the S's refer to the LEM system level FM and EA integration effort. Since the LEM system level FMEA is of primary interest for design evaluation and trade-offs they have been scheduled for the following times:

S_1 - Preliminary Design Freeze (LEM 10)

S_2 - Final Design Freeze

S_3 - Qualification Test Completed (LEM 10)

S_4 - LTA's and FTA's Completed (LEM 10)

S_5 - Six Months Prior to Delivery at AMR

S_6 - Delivery at AMR

S_7 - Scheduled Flight Dates

Generally, the equipment level FMEA's (E) are scheduled to precede each system FMEA (S). As can be seen from the schedule, there is an interplay between the information gleaned during the program as well as between the LEM's themselves. Thus, as far as LEM 10 is concerned, for example, the equipment level FM and EA will reflect the following considerations:

E_1 - based on vendor design information and mission plans

E_2 - based on vendor FM and EA, reliability assurance tests, and LTA 2

E_3 - based on vendor FM and EA, LTA's 1, 3, 6, 10 and qualification tests

E_4 - based on vendor FM and EA, and LTA's 4, 5, 7, 8, 9, and FTA's 1 and 2

Vehicle / Year	1964				1965				1966				1967				1968				1969			
Qtr.	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
FTA 1								E	S_5		S_6	E	S_7											
FTA 2									E	S_5		S_6	E	S_7										
LEM 1						E	S_2	E	S_5		S_6		E	S_7										
LEM 2						E	S_2		E	S_5		S_6	E	S_7										
LEM 3						E	S_2			E	S_5		S_6	E	S_7									
LEM 4						E	S_2				E	S_5		S_6	E	S_7								
LEM 5						E	S_2					E	S_5		S_6	E	S_7							
LEM 6						E	S_2						E	S_5		S_6	E	S_7						
LEM 7						E	S_2						E	S_5		S_6	E	S_7						
LEM 8						E	S_2							E	S_5		S_6	E	S_7					
LEM 9						E	S_2								E	S_5		S_6	E	S_7				
LEM 10				E_1	S_1	E_2	S_2			E_3	S_3		E_4	S_4		E	S_5		S_6	E	S_7			

FAILURE MODE AND EFFECT ANALYSIS MILESTONE SCHEDULE

E = Equipment Level FMEA's

S = System Level FMEA's

3.7 LEM Reliability Control Computer Program

The development schedule of the LEM Reliability Computer Program (LRCP) was revised during this quarter to reflect the MSC desire for an operational failure reporting computer program with the capability of generating weekly data tapes for MSC. In accordance with the procedural outline contained in the LEM Quarterly Reliability Status Report, dated 1 May 1964, a detailed comparison was made of the failure reporting design requirements for the LRCP and the MSC data processing requirements as stated in NASA correspondence PR1-23-64-32, PR1-23-64-63, and the updated amendment to PR1-23-64-63. The existing variances necessitated many changes to the planned LRCP contents. However, it was recognized that the alteration of the program input requirements could be accomplished without the major schedule slippage and large expenditure of a reprogramming effort. Studies were made of the possible approaches to a revision of the LRCP to include the MSC data items and codes. Some of the methods considered were:

1. Duplicate LRCP tapes for transport to MSC
2. Develop a separate MSC computer program
3. Translate and transpose from LRCP input data
4. Translate and/or transpose from LRCP central file
5. Transpose from LRCP input data

A presentation was made on 12 and 13 May 1964 at which a revised LRCP development plan, calculated to produce a computer program mutually agreeable to MSC and GAEC, was outlined for MSC representatives. At MSC direction, a request for a contract change authorization to amend the LRCP development as presented, with the exception of a data tape transposition program, was prepared and submitted. Although approval of this request has not been received at GAEC, revision of the failure reporting computer program was undertaken in order to adhere to the development schedule described in the MSC presentation. Input formats to the LRCP were changed to include elements of data requested by MSC and field sizes were adjusted to correspond to the requested coded entries. Look-up tables also were added in order not to compromise the GAEC requirement for non-coded outputs. Transmittal sheets were developed for the failure reporting, failure analysis and corrective action sections of the LRCP to facilitate data preparation for the operational program to shorten the duration of the program checkout period, and to serve as permanent records of program transactions. Copies of these transmittal forms are shown in Figures 3-7-1, 3-7-2, and 3-7-3. Finally, in compliance with the MSC request contained in NASA corres-

3.7 LEM Reliability Control Computer Program (continued)

pondence, NAS 9-1100, PPS-23-64-235, the exact formats of GAEC failure data input records, including field lengths, and the sequence of records on tape were forwarded to MSC.

EDP activity has continued concurrently in the areas of test identification and parts control. A limited version of the latter presently is undergoing an extensive checkout preparatory to the submittal of operational data. Input and output formats for the test identification program have been designed and this section of the LRCP will be completed subsequent to the failure reporting assignment.

The integrated aspects of the LRCP have been retained and all parts of the program will be accessible through any one of multiple designations of a unique item. This will be accomplished through a computer routine which will equivalence a limitless number of external numbers to specific stored data entries.

FIGURE 1

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
LEM RELIABILITY COMPUTER PROGRAM
CORRECTIVE ACTION TRANSMITTAL SHEET

DATE: ____________

PREPARED BY: ____________ EXT: ________

NUMBER 1 CARD

CODES	PART NUMBER	PART NAME	CORRECTIVE ACTION REPORT NUMBER	C.A REPORT DATE YR. / MO. / DA.	# ASSOC FAILURE REPORTS		NC	SEQUENCING
1 4								
1–6	7–26	27–46	47–58	59–64	65–67		72	73–80

NUMBER 2 CARD

CODES	C.A RESPONSIBILITY ●	C.A REQUEST DATE YR. / MO. / DA.	C.A DUE DATE YR. / MO. / DA.	C.A COMPLETION DATE YR. / MO. / DA.	C.A EFFECTIVE DATE YR. / MO. / DA.	CORRECTIVE ACTION EFFECTIVITY	CORRECTIVE ACTION STATUS		
2 4									
1–6	7–11	12–17	18–23	24–29	30	36–51	52–57		73

NUMBER 3 CARD ASSOCIATED FAILURE REPORT NUMBERS (10 COLUMNS PER FAILURE REPORT NUMBER)

CODES								
3 4								
1–6	7–16	17–26	27–36	37–46	47–56	57–66		73–80

NARRATIVE CARDS

CODES		
4 4	7	73
4 4	7	73
4 4	7	73–80
4 4		

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

CODING INSTRUCTIONS:

1. Column 1 – Card Number
2. Column 3 – Corrective Action
3. Column 5 – Transaction Codes:
   1 – Addition
   2 – Deletion
   5 – Change
4. Alphabetical characters are written as follows.
   A B C D E F G H I J K L M N Ø P Q R S T U V W X Y Z
5. Numerical characters are written as follows
   1 2 3 4 5 6 7 8 9 0
6. Write clearly so that a minimum of deciphering is required at keypunching and verifying time
7. NC – Number of Narrative Cards to be read
8. ● M4-1, GAEC Dept. Code

ENG 375.3 6-64

FIGURE 2

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
LEM RELIABILITY COMPUTER PROGRAM
FAILURE ANALYSIS TRANSMITTAL SHEET

DATE: ______
PREPARED BY: ______ EXT: ______

NUMBER 1 CARD

CODES	PART NUMBER	PART NAME	FAILURE ANALYSIS REPORT NUMBER	F.A. REPORT DATE (YR. / MO. / DA.)		N C.	SEQUENCING
1 3							
1–6	7–26	27–46	47–58	59–64		72	73–80

NUMBER 2 CARD

CODES	TEST TYPE * S	ENVIR TYPE * F	ENVIRONMENT DEGREE	TEST PLAN NUMBER	TEST REPORT NUMBER	FAILURE REPORT NUMBER
2 3						
1–6	7–9	10–11	12–21	22–41	42–61	62–71

NUMBER 3 CARD

CODES	FAILURE DURING * S	FAILURE SYMPTOM * H	FAILURE MODE * M	FAILURE CAUSE * G	FAILURE DISP * D	ELAPSED TIME FAILED PART * L	CORRECTIVE ACTION REQUEST NUMBER	FAILURE CLASS * B	ACTION TAKEN * O	FAILURE ANALYSIS REPORT SOURCE ⓧ	ΔF.A. REC COR ACT. * U	HUMAN FACT 1 * HF1	HUMAN FACT 2 * HF2	HUMAN FACT 3 * HF3
3 3														
1–6	7–9	11–13	15–17	18–20	21–23	24–28	29–40	41–43	44–46	47–51	52–54	55–57	58–60	61–63

NARRATIVE CARDS

CODES		
4 3		
4 3	7	72 73–80
4 3	7	
4 3	7	72 73–80

CODING INSTRUCTIONS:

1. Column 1 – Card Number
2. Column 3 – Failure Analysis
3. Column 5 – Transaction Codes:
   1 – Addition
   2 – Deletion
   5 – Change
4. Alphabetical characters are written as follows:
   A B C D E F G H I J K L M N Ø P Q R S T U V W X Y Z
5. Numerical characters are written as follows:
   1 2 3 4 5 6 7 8 9 0
6. Write clearly so that a minimum of deciphering is required at keypunching and verifying time.
7. NC – Number of Narrative Cards to be read
8. ΔF.A. Rec. Cor. Action – Failure Analysis Recommended Corrective Action
9. * – MSC Codes
10. ⓧ – See H4-1

ENG 375-1 6-64

FIGURE 3

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
LEM RELIABILITY COMPUTER PROGRAM
FAILURE REPORTING TRANSMITTAL SHEET

DATE: ____________

PREPARED BY: ____________ EXT: ____________

NUMBER 1 CARD

CODES	PART NUMBER	PART NAME	FAILURE REPORT NUMBER	EVENT DATE YR. / MO. / DA.	REPORT DATE YR. / MO. / DA.	# RELATED FAILURE REPTS	N.C.	* SEQUENCING
1 2 (1–6)	7–26	27–46	47–56	57–62	63–68	69–71	72	73–80

NUMBER 2 CARD

CODES	PART VENDOR ⓧ	PART LOT OR SERIAL NUMBER	PART REFERENCE DESIGNATOR	GSE FLT.	VENDOR PART NUMBER	FAILURE SITE * A	FAILURE REP'T. SOURCE ⓧ		
2 2 (1–6)	7–11	13–19	21–32	34	36–55	57–59	61–65		73–80

NUMBER 3 CARD

CODES	NEXT HIGHER ASSEMBLY NUMBER	NEXT HIGHER ASSEMBLY NAME	NEXT HIGHER ASSEMBLY REFERENCE DESIGNATOR	NHA LOT OR SERIAL NUMBER		
3 2 (1–6)	7–26	28–47	49–60	61–67		73–80

NUMBER 4 CARD

CODES	SUBSYSTEM NUMBER	SUBSYS. NAME * R	SYSTEM NAME		
4 2 (1–6)	7–26	28–30	32–47		73–80

ASSOCIATED FAILURE REPORT NUMBERS (10 COLUMNS PER FAILURE REPORT NUMBER)

CODES							
5 2 (1–6)	7–16	17–26	27–36	37–46	47–56	57–66	73–80

NARRATIVE CARDS

6 2	7–72	73–80
6 2	7	
6 2	7	
6 2		

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

CODING INSTRUCTIONS:

1. Column 1 – Card Number
2. Column 3 – Failure Reporting
3. Column 5 – Transaction Codes:
   1 – Addition
   2 – Deletion
   5 – Change
4. Alphabetical characters are written as follows:
   A B C D E F G H I J K L M N Ø P Q R S T U V W X Y Z
5. Numerical characters are written as follows:
   1 2 3 4 5 6 7 8 9 0
6. Write clearly so that a minimum of deciphering is required at keypunching and verifying time.
7. NC – Number of Narrative Cards to be read
8. GSE/F.I. – Ground Support Equipment/Flight Indicator
   For GSE enter G, for Flt. enter F, for both enter B
9. * – MSC Codes
10. ⓧ – See H4-1

ENG 375.2 6-64

4.0 SUBSYSTEM ENGINEERING

General

During this quarterly period effort was expended in each subsystem in the areas of configuration analysis, failure mode and effect analysis, proposal evaluation, review of program plans and vendor liaison. Updated reliability estimates are presented for the propulsion and RCS subsystems. As will be noted in each subsystem section below, configurations are still changing or under study such that comparison between estimated and allocated reliabilities cannot necessarily be used as trend indicators.

The status of vendor reliability program plans as of July 1, 1964 is shown in Table 4.1 below.

4.1 Propulsion Subsystems

4.1.1 Summary

During this report period a study of mission success paths for the ascent and descent propulsion subsystems was performed. The paths of operation internal to the respective main propulsion subsystems are noted in Reference (a). Results of this study will be used to facilitate the computer mechanization of subsystem and system reliability estimations.

The main effort of subsystem reliability has been directed to a Failure Mode and Effect Analysis (FMEA) of LEM subsystems, including each main propulsion subsystem. The purpose of the FMEA is to highlight design and operational weaknesses, if present, and to provide a basis for extending the existing reliability paths for future use in trade-off studies. In addition, the analysis will provide for a logical and effective integration of FMEA's on subsystem and component levels of assembly, to accomplish the intended function of a complete LEM FMEA.

Near the close of the report period, investigation of the effect on subsystem reliability of a proposed configuration change from ambient to supercritical helium storage, for the main propulsion subsystems, was begun. A report of investigation results will be prepared during the next reporting period.

TABLE 4.1

Reliability Progress Plan Status (As of 7-1-64)

Vendor	Hardware	Contract Date	Date Due	Date Received	Date Evaluated	Accept/Reject	Applicable Means	Comments
Marquardt	RCS Engines	7-22-63	9-22-63	10-21-63	11-6-63	Rejected	LM O-550-162	Disagreement with Reliability Assurance Analysis & Test Program. Resubmittal due 7-20-64.
Bell Aero	RCS Tanks	3-13-64	6-1-64					Not yet received
RCA	Comm.	2-13-64	3-25-64	4-9-64	5-5-64	Conditionally Accepted	LLR-170-498	Clarification due 7-5-64
RCA	Radars	11-7-63	12-7-63	12-20-63	1-17-64	Rejected	GAEC TWX #170-507 1-17-64	Test Section Unresolved. Not yet resubmitted.
Allison	Prop. Tanks Desc. Stage		1-28-64	1-28-64	2-28-64	Accepted	LMO-550-248	
Aerojet - General	Prop. Tanks Asc. Stage		8-5-64					
Radiation	PCMTEA	11-27-63	2-15-64	2-24-64	3-18-64	Conditionally Accepted	LMO-550-240	Resubmittal due 6-1-64 Not yet Received.
Hamilton Standard	ECS	7-9-63	9-9-63	9-22-63	12-4-63	Rejected	LMO-550-176 LMO-550-274	Not yet resubmitted
Rocketdyne	Descent Engine	5-2-63	6-1-63	6-17-63	6-19-63	Accepted	2-28-64	

TABLE 4.1 (continued)

Reliability Progress Plan Status (As of 7-1-64)

Vendor	Hardware	Contract Date	Date Due	Date Received	Date Evaluated	Accept/Reject	Applicable Means	Comments
STL	Descent Engine	7-3-63	8-3-63	8-3-63	8-13-63	Accepted	LMO-550-270 4-13-64	
Bell	Ascent Engine	7-3-63	9-19-63	9-19-63	9-24-63	Rejected	LMO-550-135 7-9-64	
Pratt & Whitney	Fuel Cell Assembly	9-19-63	11-5-63	11-5-63	1-7-64	Accepted	LMO-550-267 4-10-64	
Kearfott	Rate Gyro Assembly	3-24-64	4-24-64	5-18-64	5-20-64	Conditionally Accepted	LMO-550-317	Clarification not yet received.
RCA	ATCA	4-29-64	5-29-64	6-9-64	6-12-64	Rejected	LMO-550-338	Disagreement with Reliability Assurance Test & Analysis Sections.

4.1.2 Major Effort Anticipated For Next Quarter

Reliability effort for the next reporting period will be directed toward:

1. Continuation of a Failure Mode and Effect Analysis of the propulsion subsystems.
2. Evaluation of proposed configuration changes and their effects on the estimated reliability of the affected subsystem.
3. Revising the reliability estimates of the propulsion subsystems to reflect the latest mission profile, as noted in Section B.

4.1.3 Estimated Reliability Of Current Propulsion Subsystems

Reliability estimates for the total LEM mission of the current subsystem configurations depicted in Reference (a), are summarized in Table 4.1.3.1.

The crew safety estimate was prepared using the following assumptions:

a. ~~Subsystem reliability at initiation of powered descent~~ is approximately 1.0.

b. Clear pericynthion orbit is attained after a 24 hour lunar stay.

Reliability estimates for the Bell ascent and Rocketdyne descent engines listed in Table 4.1.3.1, were obtained from Reference (a). The reliability estimate for the STL descent engine represents the vendor estimate based on the specification mission rather than the mission profile of Reference (a).

4.1.4 Discussion

4.1.4.1 Failure Mode and Effect Analysis

The Failure Mode and Effect Analysis (FMEA) of the main propulsion subsystems will be incorporated in the FMEA for the complete LEM system. Rather than a detailed FMEA for each component, to be performed by the respective vendor, groups of components that collectively perform intended functions are being considered in this analysis. Failure is defined

TABLE 4.1.3.1

PROPULSION SUBSYSTEM SUMMARY

Equipment	Reliability			
	Apportioned		Estimated	
	Mission Success	Crew Safety	Mission Success	Crew Safety
Ascent Propulsion Subsystem:	.999961	.999976	.998772	.999768
Engine	.999982	.999982	.999633	.999902
Propellant Pressurization and Feed	.999979	.999994	.999139	.999866
Descent Propulsion Subsystem:	.999075	.999998	*.996528 **.998973	
Engine	.9991	.999999		
Rocketdyne*			.997384	
STL**			.999831	
Propellant Pressurization and Feed	.999975	.999999	.999142	

4.1.4.1 Failure Mode And Effect Analysis (continued)

as loss or degradation of the intended function of the component group. The effect of failures noted in the subsystem FMEA include the effect on the total LEM mission as well as on the particular subsystem. Preliminary results of this effort will appear during the next period.

4.1.4.2 Ambient Versus Supercritical Helium Storage

A subsystem configuration change of main propulsion pressurization from ambient to supercritical helium storage has been proposed to effect a weight saving for the LEM (Reference (b)). Investigation of the effect on subsystem reliability of the proposed configuration change was begun near the close of the report period.

Early results indicate an appreciable decrease in vehicle separation weight and some degradation of subsystem reliability. Further study of different configurations of equipment may reveal ways of circumventing the failure modes of the supercritical helium storage and so decrease the reliability degradation imposed. In any event, the possible weight saving effected makes further investigation mandatory.

An account of investigation results will be published in the next report period.

4.1.5 Vendor Status

4.1.5.1 Ascent Engine - Bell Aerosystems Company

The Bell Ascent Engine Program Plan (Reference (c)) including the Reliability Plan submitted by Bell Aerosystems Company, has not yet been approved by GAEC. Comments regarding this document were sent to BAC listing the revisions required prior to acceptance (Reference (d)). The Program Plan and Reliability Plan were also discussed in a meeting with BAC at GAEC on 13, 14 and 15 April 1964. (Reference (e)) The revised Program Plan (Reference (f)) has been received at GAEC and is presently being reviewed for acceptance.

The preliminary Reliability Report (Reference (g)) has been reviewed and found to be unacceptable. Comments regarding this report were prepared (Reference (h)) and discussed with

4.1.5.1 Ascent Engine - Bell Aerosystems Company (continued)

BAC at the BAC/GAEC April meeting (Reference (e)). The report now being revised was expected to be submitted to GAEC for review on 15 June 1964.

4.1.5.2 Descent Engine - Rocketdyne

The Rocketdyne Descent Engine Program Plan (Reference (j)) has been reviewed and is in the process of being formally accepted by GAEC. The Preliminary Reliability Report (Reference (k)) has been accepted by GAEC per Reference (l).

4.1.5.3 Descent Engine - STL

The STL Descent Engine Program Plan (Reference (m)) and the Preliminary Reliability Report (Reference (n)) have been accepted by GAEC per References (p) and (q) respectively.

4.1.6 References

a. ~~LEM Mission Success Paths for Propulsion Subsystems~~
LED-550-31   19 June 1964   GAEC

b. Weight Comparison of Ambient and Supercritical Helium Pressurization Systems
LMO-490-124   24 June 1964   GAEC

c. Program Planning Report No. 8258-910002
16 September 1963   Bell Aerosystems Company

d. Comments on Program Planning Report
LLR-170 154   17 October 1963   GAEC
(LMO-275-14   16 October 1963)

e. Meeting with Bell Aerosystems on 13, 14 and 15 April 1964
LMO-550-288   1 May 1964   GAEC

f. Program Planning Report No. 8258-910002(A)
30 June 1964   Bell Aerosystems Company

g. Reliability Report No. 8258-932993
27 November 1963   Bell Aerosystems Company

4.1.7 References (continued)

h. Comments on Bell Reliability Report
LLR-170-384 20 March 1964 GAEC
(LMO-550-197 30 January 1964)

j. Reliability Program Plan R-5177-1
1 September 1963 Rocketdyne

k. Preliminary Reliability Report R-5226-2
December 1963 Rocketdyne

l. Approval of R-5226-2
LTX-170-690 3 March 1964 GAEC

m. Reliability Program Plan 8438-6003-SW002
13 March 1964 STL

n. Preliminary Reliability Report 8438-6084-SU000
1 April 1964 STL

p. Approval of STL Program Plan
LMO-272-23 27 April 1964 GAEC

~~q. Approval of STL Reliability Report~~
LMO-276-60 2 July 1964 GAEC

4.2 Reaction Control Subsystem

4.2.1 Summary

The RCS configuration has changed since the last quarterly. The changes that have been made are as follows:

a. The burst disc and filter have been eliminated in the propellant lines

b. The main shut-off valves have been made normally closed

c. The crossfeed valves have been changed from squibs to solenoids.

Efforts during this quarter were directed along the lines of path studies, configuration studies, failure mode and effect analysis, vendor liaison, and component evaluation. Table 4.2.1 is a summary of the estimated and apportioned reliability goals.

TABLE 4.2.1

SUBSYSTEM ANALYSIS

Equipment	Reliability*				Weight	
	Apportioned		Estimated			
	Mission Success	Crew Safety	Mission Success	Crew Safety	Apportioned	Estimated
Helium Pressurization and Controls and Propellant Tankage	.999902	.999959	.998646	-	-	749.2
Thruster Installation Assembly	.999902	.999976	**.992968	-	-	121.5
Total RCS	.999804	.99935	.991624	.9999	-	870.7

* Not updated since last quarterly.

** Details of change will be issued in LED shortly and be explained in more detail next.

4.2.2 Major Efforts Anticipated in Next Quarter

During the next quarter the Function Failure Mode and Effect Analysis will be continued. Measurements will be studied in detail with a decision to either add or delete specific measurements. A continuing effort in the updating of failure rates will continue. Vendor monitoring will continue with increased emphasis in the component area. Negotiations will continue on vendor proposals. The Marquardt Corporation and the Bell Aerosystems Company will be visited for Quarterly Program and Design Reviews.

4.2.3 Discussion

4.2.3.1 Path Studies

The subject studies and related estimates have been prepared in order to further define the RCS subsystem reliability. Essentially this study includes:

1. An analysis of the modes of operation at the RCS.
2. A phase-by-phase breakdown of the mission with respect to the RCS.
3. Ground rules for the RCS thrusters.
4. Generation of reliability models for the respective phases.
5. Equipment reliability estimates for each mission phase based upon failure rate data, duty cycle per phase and environmental stress factors.

Reliabilities have been calculated for each element in the complete RCS for the ten separate mission phases in accordance with reference (a).

The duty cycle for each thrust chamber assembly was computed with duty cycle data provided by a single engine operating a total of approximately 100 seconds. This operating time is considerably less than the total operating life of 1000 seconds.

Reference (b) is a formal report detailing the ground rules and estimates used in the path study.

4.2.3.2 Configuration Studies

4.2.3.2.1 Helium Squib Valves

In this case, reliability compared two explosive actuated valves with a single initiator in each versus a single explosive actuated valve with two (dual) initiators. The reliability of the former is .999999 and the latter .999998.

From experience it has been found that exposive actuated valves have a low probability of failure. Like all valves the predominant failure mode is leakage in the closed position once the valve has been operated (The leakage is across the seat). If a valve is seated and has not leaked, failure is very unlikely until it is cycled. As can be seen from this discussion, the valve and connections are highly reliable and the primary area of concern is the squib.

As shown above, the single valve with dual initiators shows a negligible decrease in reliability. However, weight tradeoff indicates a weight savings for this configuration.

At this time NASA-MSC has decided to go with the original design (two valves with single initiators) since it is a common usage item with NAA, on the Service Module.

4.2.3.2.2 Burst Disc, Filter and Main Shut-Off Valve

This analysis considered the possibility of eliminating the burst disc and filter downstream of the propellant tanks and keeping the main shut-off valve normally closed. The reliability of the proposed configuration is .999855 as opposed to .999895 for the current configuration. The current configuration is forty parts in a million higher in reliability than the proposed configuration. The advantages of eliminating the burst disc and filter are: a reduction in weight of 3.2 dry lbs, and a failure in the normally closed main line shut-off valve will be detected sooner than in the current configuration.

Based on the above, and the fact that the normally open TCA isolation valves can be used as a backup in case of the main S/O valve malfunction, Reliability recommended that the proposed configuration be used. This has been agreed to by GAEC Project and the change is in progress.

4.2.3.3 RCS Reliability Input to Revised PS/TCA Proposed Specification

Minor reliability modifications have been incorporated into the revised specification in the areas of numerical reliability, safety and operational profile. A mission profile for reliability estimates has been included in the specification (see Section 3.2). A nominal mission duty cycle for each thruster will be supplied at a later date. The modifications are included in Reference c.

4.2.4 Vendor Status

4.2.4.1 Marquardt Corporation

As previously mentioned in this report propellant burst disc and filter requirement has been deleted. The N/C main line shut-off valve will be a common usage item along with the ascent interconnect valve. Also, the crossfeed valves are now solenoids and are common usage items with both the ascent interconnect and main line S/O valve with GAEC having primary responsibility.

~~TMC has completed the initial items list and criticality~~ ranking for the S/M qual. engine design.

It is expected that GAEC reliability personnel will visit TMC this quarter on quarterly program status, design revisions and technical coordination meetings with associate vendors.

The revised program plan and reliability reports have not been received. They are expected this coming quarter.

4.2.4.2 Bell Aerosystems Company

At the present time, NAA favors a single-ply bladder design in place of the three-ply bladder. Bell had previously showed in their service module tankage subsystem proposal a failure rate of 13000×10^{-6} per expulsion cycle for single-ply teflon bladder and speculated on a failure rate of 100×10^{-6}, per expulsion cycle for a three-ply teflon bladder which would be acceptable. The figure of 13000×10^{-6} would completely dominate the reliability of the tankage subsystem while 100×10^{-6} would not cause a change in the analysis of the tankage subsystem (GAEC tank specification indicates that a failure rate of 500×10^{-6} is acceptable).

4.2.4.2 Bell Aerosystems Company (continued)

Bell has concluded that the bladder contributes 99.93% of the tank unreliability (see Reference (d)).

A problem Bell has been encountering is related to the teflon material used in the bladders. Permeability characteristics (above 26 psi vapor pressure) of the teflon permits the N_2O_4 vapor to penetrate the inner-ply of the bladder. This causes gaseous "pockets" between the two inner-plys thereby precluding 100% expulsion of propellant.

The Program Plan is expected this coming quarter.

4.2.5 Vendor Proposal Evaluations and Negotiations

Table 4.2.2 is a listing of the status of lower tier RCS vendors responsible to GAEC. As can be seen from the dates no documentation has been received this quarter.

4.2.6 References

a. Memorandum (informal), Subsystem Reliability Estimation dated 27 March 1964.

b. LED-550-28, "RCS Reliability Ground Rules and Estimates for Success Path Study" dated 25 May 1964.

c. LMO-550-281, "Reliability Input to Revised PS/TCA Proposed Specification" dated 27 April 1964.

d. Bell Letter 8:32:4:0608-1 TJC, "Model 8339 - LEM RCS Tank Program" dated 8 June 1964.

TABLE 4.2.2

VENDOR STATUS SUMMARY

Vendor	Component	Proposal Evaluation	Negotiations Status
			(Technical Aspects Only)
Electrada Corporation Airite Division	Helium Tank	Completed 3/5/64	Completed 5/7/64
VACCO	Helium Filter	Completed 4/23/64	To Be Negotiated 7/5/64
APCO	Quad Check Valve	Completed 6/1/64	Completed 6/26/64
Purolator (On The Mark Division)	Helium Disconnect Couplings	Completed 6/2/64	Completed 7/2/64
Parker Aircraft Company	Propellant Latch Type Solenoid Valves	Completed 3/18/64	Completed 6/14/64
~~Fairchild Stratos~~	~~Regulator:~~ (Helium Pressurization - 2 Stage)	~~Completed 5/15/64~~	~~Completed As Of~~ 7/8/64
Giannini	Propellant Quantity Gaging System	Completed 5/5/64	Open - Not Completed
Sargent/Fletcher	Helium Latch Type Solenoid Valve	Completed 6/3/64	Completed 6/24/64
PELMEC	Explosive Squibs (Helium)	Completed 4/22/64	To Be Negotiated 7/13/64
Parker Aircraft Company	Ascent Interconnect Crossfeed Valves	Completed 3/15/64	Completed 5/10/64
J. C. Carter	Coupling - Fill Drain and Service	Completed 3/20/64	Completed 6/15/64

4.3 Electronic Packaging

Throughout this report period, the largest reliability effort has been in the area of technical monitoring and assistance. This has been accomplished through the mediums of:

1. Review of and comment on documentation, e.g., proposals, packaging studies and reports.
2. Attendance at packaging presentations and technical coordination meetings.

Other effort was expended in the following areas:

1. Further coordination with Francis Associates to make the ERA test model more representative.
2. Contributions to a test plan for the evaluation of the split pin wire wrap connection and its associated coating and the determination of the number of permissible rewraps before degradation of the connection.
3. Contributions to the formulation of a humidity test of the split pin wire wrap connection.

4.3.1 Technical Monitoring And Assistance Areas

A number of equipment designs have advanced to the point where considerable progress has occurred in packaging. This section of the report will give noteworthy packaging information on a specific equipment basis.

4.3.1.1 LEM Radars

A meeting was held at GAEC on 13 April 1964 to discuss Radar Packaging Concepts (see Reference (a)). RCA presented a configuration which shall hereafter be referred to as the segmental design approach. Briefly, this design was composed of modular sections held together with four long skewer bolts. This was proffered by RCA in lieu of the approach in the GAEC Electronic Packaging Specification, LSP-360-002. GAEC pointed out several undesirable features of a segmented design to RCA and requested RCA to study it more carefully. They were also requested to make a thorough quantitative analysis and directly compare the two designs.

4.3.1.1 LEM Radars (continued)

On 4 June 1964 RCA made a LEM radar packaging presentation to GAEC at Bethpage, New York (see Reference (b)). At this time RCA presented the segmental approach in more detail. Next, they went into a description of their proposed internal electronic subassembly packaging design. This is a marked deviation from the specified methods in LSP-360-002. RCA referred to the method of assembly as a single web, center plate cordwood design. The center plate was drilled to hold the piece-parts which were mounted directly through the plate. The plate was used to immobilize the parts and provide heat sinking. A minimal circumferential conformal coat was applied between plate and part. Component interconnections were accomplished by printed circuit boards.

At this time the following main reliability objections were presented to RCA.

A. Against The Segmental Design

1. Inherently during handling and assembly there are occasions when this design can bow, thus, stressing internal connections.
2. Chafing of the metal forces of segments could create EMI problems.
3. Vibration of the edges of the segmented flanges could scar the cold plate dirupting efficient heat removal.
4. Thermal excursions could cause the skewers to yield with a resultant chattering of the segments under vibration. This could embarass connections and also cause EMI problems.
5. During assembly and maintenance actions the segments can splay upon removal of the skewer compression. To affect removal of a segment the segments on either side must be spread. Both of these actions put stress on the wire wrap connection. Undue exercising of the EMI gasketing also occurs.
6. The segmental design will not readily lend itself to sealing if this becomes advisable.

4.3.1.1 LEM Radars (continued)

B. Against The Center Plate Cordwood Assembly

1. Parts held in the holes of a metal web are subject to guillatining under thermal excursions if clearance is restricted. It should be noted that efficient heat removal requires a close fit. Oversize parts would aggravate this situation.

2. This technique does not lend itself to inspection for completeness of the coating. (Incomplete coating could result in thermal overstressing of the associated part.)

3. If transistors are located inside the stack it might be impossible to heat sink them during soldering operations.

4. The majority of heat generating components dump their heat most readily through their leads. Therefore, this design could be improved by adding encapsulant or wrapping foil around the component critical bodies.

5. This design compromises dense packaging. It should be remembered that as component density increses the web metal descreses. This means heat sinking efficiency decreases.

Other objectionable features in other engineering areas were pointed out to RCA so that they were asked by GAEC to abandon the segmental approach andadopt a continuous outside case wall for the ERA. They were also requested to remove the objectionable features of their subassembly design.

4.3.1.1.1 Landing Radar

In addition to the preceding shortcomings the landing radar is not mounted on cold plate rails. Thus, it has an aggravated thermal problem. It falls into the category of thermal packaging for transient operation. As such, mass (thermal capacity) should be around critical heat generating components. This is lacking in the present center plate cordwood subassembly. Actually, this design should be adjusted so that each component approaches its maximum operating temperature simultaneously. In this way no single thermally overstressed component would be a potential early failure which could prematurely remove the landing radar from service.

4.3.1.2 Carbon Dioxide Sensor

The Perkin-Elmer Corporation has submitted a proposal for this unit (see Reference (c)). From the proposal, it appears that they intend to use solid conductor wire for interconnections without encapsulation support. If possible, this should be avoided and alternate designs will be explored with Perkin-Elmer during negotiations.

4.3.1.3 Control Coupler Assembly

A sizing estimate, dated 21 May 1964, was prepared on this unit by Francis Associates. It was estimated the unit would contain greater than 125 crystal can relays. Considerable reliability exercises and monitoring will be required in the relay area alone. Considerable digital circuitry will make up this unit. It would appear that some weight, power and reliability gains could be made by using integrated circuits for the logic functions. Due to the probably high density packaging of the logic, it is possible for heat to stagnate for these devices. This should be accounted for in the design. Fan-in and fan-out derating should be a consideration.

4.3.1.4 Communication

A packaging study has been prepared by RCA for the communication equipment (see Reference (d)).

The questionable reliability features of the RCA approach are given in References (e) and (f). The most urgent items are given below.

1. Use split pin wire wrap rather than separated pins. This would avoid the use of solid conductor wire, reduce the number of connections by one half and use a technique evaluated by MSC.
2. The RCA method of pin block mounting creates "pockets." These can collect dust, debris and trap moisture. They should be eliminated by flush mounting.
3. The wiring harness should have compliance loops for strain and vibration relief.
4. RCA is suggesting the use of right angle coaxial connectors. These should be avoided by alternate designs.
5. RCA indicates that the diplexers will be mounted to the ERA case and not to the cold plate. They should investigate cold plate mounting in order to avoid a possible detuning problem resulting from dimensional changes during large thermal excursions.

4.3.1.4 Communication (continued)

6. In the referenced packaging study, RCA indicated a necessity to test for multipacting. In recent coordination meetings they have not given any plans to obviate the occurrence of multipacting. They also have indicated no plans to do radioactive initiatory exploratory testing for it.

7. RCA has not given any details for the packaging of the electronic subassemblies.

4.3.2 Evaluation Of Split Pin Wire Wrap

On 3 June 1964 an engineering team from MSC visited GAEC for the purpose of discussing MSC's test plan for evaluating split pin wire wrap. In a working meeting the entire plan was reviewed and comments from GAEC were favorably received and incorporated into the plan at appropriate places.

This plan will rigorously test both split pin wire wrap and the coating used in the test model.

The testing will be quite comprehensive. It should be noted, in particular, that a dynamic delta resistance (electrical noise) check will be done following groups of specified rewraps. The coating will be checked by humidity and leakage tests after environmental exposures. Groups of wire wraps will be rewrapped in progressively higher quantities. This will help determine the number of rewraps possible before electrical degradation of the connection. Testing is expected to begin in October of 1964.

4.3.3 High Humidity Testing

No ideal coating for the wire wrap has been located as yet. A Grumman internal test is being conducted to determine humidity effects on a sample of wire wrap (see Reference (g)). This will be run without and with several coatings.

4.3.4 Reference List

(a) Minutes of Technical Coordination Meeting, LMM-372-14, GAEC, Dated 13 April 1964

(b) Minutes of Technical Coordination Meeting Between GAEC and RCA, LMM-370-20, GAEC, Dated 4 June 1964

(c) Sensor, Carbon Dioxide Partial Pressure, Report No. 7642, Perkin-Elmer, Norwalk, Connecticut, Dated 30 March 1964

(d) Packaging Study, Communication Subsystem, Dated 11 May 1964, RCA

(e) Arleth, J., Reliability Comments on RCA Communications Packaging Study, LMO-550-322, Dated 9 June 1964

(f) Arleth, J., Reliability Comments on RCA Communication Subsystem Monthly Status Report of 30 April 1964, LMO-550-315, GAEC, Dated 1 June 1964

(g) GAEC Test Request by A. Shreeves and J. Albonese, No. 10240-687-027, Dated 24 June 1964

4.4 Guidance And Control

4.4.1 Summary

During this report period, the following reliability effort has been expended in the Guidance and Control area. As delineated in the last quarterly report the amalgamation, of the Navigation and Guidance subsystem and the Stabilization and Control subsystem has been continued because of their close interdependence. Those areas which were specifically investigated and the associated documentation are outlined as follows:

4.4.1.1 Primary Guidance and Navigation Section

a. Updating alternate path study for determination of mission success for the guidance and control function, LMO-550-319.

b. Review, comment and approval of following GAEC/MIT ICD's:

- L1S-300-10001
- L1S-300-10005
- L1S-370-10006
- L1S-540-10003
- L1S-540-10004

c. Review of the technical documentation submitted by IBM on the Triple Modular Redundant Computer.

d. Initiated Failure Mode and Effect Analysis.

e. Review of LEM Top Specification, LMO-540-248

f. Review of following AC Spark Plug documentation:

- Quarterly Reliability Progress Report, (Jan., Feb., Mar., 1964)
- Monthly Reliability Progress Report (Jan. 1964)
- Monthly Reliability Progress Report (Feb. 1964)
- Monthly Reliability Progress Report (Apr. 1964)

4.4.1.2 Rendezvous Radar and Landing Radar Section

a. Review of and comment on the following RCA/Ryan documentation:

- LMR-(P)-3100-5, March Monthly Status Report LMO-550-308

4.4.1.2 Rendezvous Radar and Landing Radar Section (continued)

a. (continued)

- LMR-(P)-3100-6, April Monthly Status Report, LMO-550-350
- LQR-(P)-3100-1, March Quarterly Design Report, LMO-550-276
- LESP-(B)-3600, LEM Specification for Landing Radar, LMO-550-278
- LTM-(B)-3200-5, RCA Orbit Circularization Trade-Off Studies, LMO-550-309.
- Reliability Data List, dated 15 May 1964, LMO-550-329
- Ryan Report No. 53969-3, Landing Radar Extended Capability Study, dated 27 April 1964.

b. Reliability comments to RCA letter LCC-ASD-(P)-3200, 5100-470, dated 14 May 1964. This letter pertains to the Reliability Data List of Feb. 1964, LMO-550-312.

c. Participation in April Monthly Radar Technical Staff Meeting No. 1, GAEC/RCA, LMM 372-11, LMO-372-182.

d. Participation in May Monthly Radar Technical Staff Meeting No. 2, GAEC/RCA, LMM-372-18, LMO-372-182.

e. Participation in Reliability Meeting with RCA, June 16, 1964, to discuss Reliability Data Lists, Derating Policy, Parts Service Temperature, Acceptable Parts List and Failure Rates, LMM-180-229.

f. Initiated Failure Mode and Effect Analysis for the radar section.

g. Reliability estimates of measurable functions on the Radar's Flight Measurement List.

h. Review and comment of Radar Subsystem test logic.

i. Radar interface circuit reliability evaluation, LMO-550-303.

j. Submitted inputs and/or revisions to the following specifications:

- Microwave Switch used in the X-Band Transponder Antenna Assembly, LMO-550-325
- Indicator, Altitude and Range
- Landing and Rendezvous Radar
- Cross Pointer Meters.

4.4.1.3 Abort Guidance Section

a. Submitted input and/or revision to the Abort Programmer Specification.

b. Participated in the evaluation of the ARA proposals.

4.4.1.4 Control Electronics Section

a. Completed configuration analysis of PNGS/SCS interface LMO-550-304

b. Completed configuration analysis of AC/TC limit switch LMO-550-314

c. Completed configuration analysis of different ATCA modulators, LMO-550-272

d. Reviewed the GDA and ATCA program plans.

e. Completed Reliability documentation submittal milestone charts for RGA and ATCA.

f. Completed the Reliability estimates of measurable functions on SCS Flight Measurement List.

g. Started Failure Mode and Effect Analysis.

h. Reviewed and commented on the SCS test logic

i. Determined the new SCS operating times using updated mission profile which is predicated on NASA TWX

j. Review the following vendor proposals.

- Gimbal Drive Actuator
- Attitude and Translation Control Assembly
- Attitude Indicator and GASTA
- Thrust to Weight Ratio Indicator
- Cross Pointer Meters

k. Submitted inputs and/or revisions to the following specifications:

- Gimbal Drive Assembly, LMO-550-263
- Attitude Indicator and GASTA, LAV-550-40
- Attitude Controller

4.4.1.5 LEM Mission Programmer Section

a. Configuration analysis of implementing the test function on unmanned LEM's, LMO-550-331

4.4.1.5 LEM Mission Programmer Section (continued)

b. Reviewed vendor reliability data on programmed tape reader assemblies.

c. Provided reliability input to the NASA Mission Programmer presentation.

d. Submitted inputs to the following specifications

- Decoder Assembly - equipment deleted
- Timer Assembly - equipment deleted
- Control Coupler Assembly
- Program Reader Assembly

4.4.2 Major Effort Anticipated for Next Report Period

During the forthcoming quarterly report period, as the final design concepts, of the electronic and electromechanical assemblies associated with the various sections of the Guidance and Control system, specifically the Radars, Abort Guidance, Control Electronics and Mission Programmer, become firmly established, it is anticipated that considerable reliability participation will be required. This shall include as a minimum the following tasks:

a. Evaluation of interim and final design configurations

b. Continue participation in the preparation and review of Performance Specifications and Vendor Requirements for those equipments which will be installed in all of the LEM vehicles.

c. Review of proposals and participation in vendor negotiations.

d. Liaison with vendors on the appropriate reliability models for the equipment and updating of the reliability estimates as the mission profile, part population and applicable failure rates become more clearly defined.

e. Review of vendor documentation (viz. Program Plan, Monthly Status Reports, Failure Mode and Effect Analysis etc.)

f. Perform independent configuration and circuit analysis when required.

g. The continuation of a failure mode and effect analysis on those assemblies which have completed the initial conceptual design phase.

4.4.2 Major Effort Anticipated for Next Report Period (continued)

In addition to the general reliability tasks indicated above, the following specific areas of effort will be accomplished:

a. Continued liaison with MIT and RCA on the Mission Success and Crew Safety Models for the PNGS and Radar Sections, respectively.

b. Continued review of MIT, AC Spark Plug and RCA documentation.

c. Continued review of MIT/GAEC Interface Control Documents.

d. Continue liaison with RCA on applicable failure rates for their equipment.

e. Assist in the development of the LEM Mission Programmer LAV-250-130

f. Provide reliability input to Control Coupler Assembly (CCA) proposal and perform reliability tasks delineated in CCA Vendor Requirements.

g. Continue the reliability evaluation of IBM's TMR Computer.

4.4.3 Discussion

In support of the respective subsystem groups, which are included in the Guidance and Control area (Guidance and Navigation Subsystem, Stabilization and Control Subsystem, Flight Controls Subsystem), there has been a considerable amount of circuit and configuration analysis, proposal evaluation and documentation reviews during this past quarter. The following paragraphs will briefly discuss the areas which are outlined in Sections 4.4.1.1 through 4.4.1.5.

The alternate paths, for the determination of mission success for the over-all system guidance and control function, was revised in LMO-550-319 while a preliminary estimate of the feasibility factor for each path was also included. This study will be continually updated as required and new information becomes available concerning the Guidance and Control area.

4.4.3 Discussion (continued)

The GAEC/MIT Interface Control Documents were reviewed and commented upon, to insure the compatibility of the subject documents with the performance and reliability goals of the LEM vehicle.

A review and reliability evaluation of IBM's Triple Modular Redundant Computer was initiated in this quarter and will continue into the next quarter. A trip was made to IBM Federal Systems Division, to discuss the mechanization, packaging, operation and parts population of the TMR for possible consideration on the LEM program.

The Failure Mode and Effect Analysis has been initiated on all equipments which have completed initial design in the Guidance and Control area. The FMEA will highlight design and operational weaknesses, inherent in the particular equipment design, and will provide an improved understanding, of the equipments mechanization and operation.

Those parameters in the G and C subsystems which are presently considered for monitoring purposes either by GOSS or by the astronaut were reviewed and ranked for criticality as reflected with due consideration to mission success and crew safety. The reliability of the discrete functions were also provided, to determine if a particular function must be necessarily monitored or is reliable enough so that the measurement of that particular function can be eliminated, without compromising the vehicle reliability goals.

The test logic for the complete Guidance and Navigation, Stabilization and Control subsystems were reviewed and pertinent comments were submitted to the Reliability Assurance Group. In particular, the test profiles were scrutinized for end to end testing and logical order of test performance.

A configuration analysis (LMO-550-303) considering three alternate radar interface circuits, was completed. The computations indicate the reliability, of these circuits are almost equal and the decision as to which one should be employed, should be based on performance considerations.

A comparison of two alternate configurations of PNGS/SCS interface (LMO-550-304) were analyzed: one utilizing a 102.4Kpps signal, the other utilizing a DC signal. The results show, that the 102.4Kpps signal interface failure rate is 5 times the DC signal interface failure rate.

4.4.3 Discussion (continued)

A study was performed (LMO-550-314) to determine the preferred configuration of limit switches for the Attitude and Thrust Controllers. The study investigated several configurations and recommended the use of micro switches in conjunction with transistor gates because of reliability considerations and the associated low power drain.

Several different ATCA modulator configurations (LMO-550-272) were investigated to determine which is more reliable. Of the modulators analyzed, only the "On-Off" type improves reliability but degrades the vehicle performance through increased fuel expenditure.

Considerable effort was expended during this quarter, on the LEM Mission Programmer. A study (LMO-550-331), comparing two methods of performing the test program function on the unmanned LEM's was completed. The results showed, that employing a tape reader as a backup, did increase the reliability but no indication can be given if this increase is necessary, since overall vehicle mission success goals have not been established for the unmanned LEMs. Tape reader reliability data from Tally, Fairchild, and Honeywell was reviewed since a tape reader is being considered for the unmanned LEMs. Reliability inputs were also generated for a presentation to NASA on the function, test requirements and hardware for the LEM Mission Programmer.

The performance specifications, for all G&C equipment were updated, to reflect the latest mission profiles for reliability estimates and to change those reliability apportionment where necessary. Reliability inputs were also provided for new performance specifications.

A major portion, of the effort in the Guidance and Control section, was devoted to reviewing vendor documentation and proposals, vendor contract negotiations, completing equipment milestone charts and participation in reliability meetings with various subcontractors. All available reliability comments, to these tasks, are found in the GAEC memos delineated above.

4.4.4 Vendor Status

At the end of this report period, the equipments that are under contract for the Guidance and Control Subsystem are:

a. Rendezvous Radar/Transponder and Landing Radar - RCA Burlington, Massachusetts

4.4.4 Vendor Status (continued)

b. Rate Gyro Assembly, General Precision Instrument, Kearfott Division, Little Falls, New Jersey.

c. Attitude and Translation Control Assembly, RCA, Burlington, Massachusetts.

d. Thrust to Weight Ratio Indicator, Bendix, Pioneer-Central Division.

e. Gimbal Drive Actuator, Garrett, Los Angeles, California.

4.5 Communications Subsystem

During this report period, the communication reliability effort has been extended into monitoring, coordination and direction of the vendor effort. In addition, effort has continued in the Grumman inhouse antenna and transmission system area.

4.5.1 Vendor Status

4.5.1.1 Documentation Review Effort

In this period considerable effort was expended reviewing RCA documentation regarding the design and negotiations for the communications system.

Those documents which were reviewed and the associated comment documents along with a summary or philosophy where noteworthy, follow:

a. LESP-(P)-4130A, LEM Equipment Specification, Specific Requirements for S-Band Transceiver Subassembly, 6 May 1964 RCA. Amendment #1 to LESP-(P)-4130A, 8 May 1964, RCA. Exceptions and understandings to LESP-(P)-4130A as amended, and Documents referenced therein, 7 May 1964, RCA. Comments are in LAV-381-18, E. Griffin and N. Darch, 4 June 1964, GAEC.

b. LESP-(P)-4140, LEM Equipment Specification, Specific Requirements for S-Band Power Amplifier Subassembly, 30 March 1964, RCA. Comments were made in Reliability comments to LESP-(P)-4140, R. Komuves and J. Arleth, 1 May 1964, GAEC. Comments mainly clarified the specification by adding qualifying statements to specific paragraphs. Some additional paragraphs of GAEC LSP-380-2 were included.

c. LESP-(P)-4300A, LEM Equipment Specification, Specific Requirements for Premodulation Processor and Audio Center Subassembly, 1 May 1964, RCA. Amendment #1 to LESP-(P)-4300A, 1 May 1964, RCA. Exceptions and understandings to

4.5.1.1 Documentation Review Effort (continued)

c. (continued)

LESP-(P)-4300A as amended, and Documents referenced therein, 1 May 1964, RCA. Comments are in LAV-381-15, E. Griffin and N. Darch, 28 May 1964, GAEC.

In general RCA was requested to submit a complete summary indicating where their specification differs from GAEC LSP-380-2 including amendments 1,2 and 3 thereto. They were also requested to submit backup data for all values not in LSP-380-2.

d. LESP-(P)-4600A, LEM Equipment Specification, General Requirements for Equipments, 30 March 1964, RCA. Amendment #1 to LESP-(P)-4600A, 1 May 1964, RCA. Exceptions and understandings to LESP-(P)-4600A as amended, and Documents referenced therein, 1 May 1964, RCA (for Raytheon) Exceptions and understandings to LESP-(P)-4600A as amended and Documents referenced therein, 8 May 1964, RCA (for Motorola). Comments are in LAV-381-15, E. Griffin and N. Darch, 28 May 1964, GAEC and in LLR-170-644 Enclosure (1) 15 May 1964, GAEC.

GAEC took exception to RCA's philosophy that weight, in general took precedence over maintainability and that locking devices could be omitted by such practices as bending in pins or sheet metal brackets, and substituting for the requirements of MSFC-PROC-158B.

e. LMR-(P)-4100-2, April Monthly Status Report, RCA. Comments are in LMO-550-315, J. Arleth, 1 June 1964, GAEC. In brief, GAEC requested a review of the reliability block diagrams and trade-off methodology being used in RCA's configuration analysis.

f. LMR-(P)-4100-3, May Monthly Status Report, RCA. Comments are in LAV-381-28, E. Griffin and N. Darch, 1 July 1964, GAEC. Reliability data lists, reliability assurance analysis, maintainability analysis and thermal design analysis as they affect reliability are being omitted from the monthly reports. Timely reply was requested to cover these areas.

g. LPD-(P)-4130, LEM Procurement Document S-Band Transceiver Subassembly, 18 March 1964, RCA. Amendment #1 to LPD-(P)-4130, 8 May 1964, RCA. Exceptions and understandings to LPD-(P)-4130 as amended, and Documents referenced therein, 7 May 1964, RCA. Comments are in LAV-550-43, D. Smith 26 May 1964, GAEC. GAEC pointed out that all failures

4.5.1.1 Documentation Review Effort (continued)

g. (continued)

must be reported and data must be supplied to justify qualification status. It is RCA's responsibility to enforce GAEC requirements and to deny general waivers which have not been approved by LEM Reliability.

h. Program Planning Document for LEM Communications, 3 April 1964. RCA. Comments are in LMO-550-290, J. Arleth and R. Komuves, 1 May 1964. Main reasons for rejecting the program plan are:

1. Insufficient hardware orientation.
2. RCA's interpretation of the reliability portion of the documentation requirements requires clarification.
3. Ambiguities and crossover in the scheduling of reliability tasks.

A new program plan was promised in 60 days. However, negotiations have delayed RCA. They have requested some additional time before re-submittal of their program plan.

i. Packaging Study Communications Subsystem, 11 May 1964, RCA. Comments are in LMO-550-322, J. Arleth, 9 June 1964, GAEC. Main reasons for rejecting were:

1. RCA's plan to use wire wrap layout with solid jumper interface instead of split pin wire wrap.
2. Pin block mounting pockets can collect dust and moisture.
3. Possible degradation efforts resulting from disregard of VHF Diplexer Cold Plate mounting specifications.
4. Lack of moisture control plans and reliability tradeoff studies.

4.5.1.2 Vendor Meetings at GAEC

Four meetings of paramount interest to reliability occurred during this period.

a. Reliability and Maintainability Requirements meeting on 12 May 1964. The purpose of the meeting on 12 May 1964 was to acquaint RCA with the GAEC philosophy pertaining to the reliability goals as related to the mission profile and the modes of operation of the communication system. Complete details appear in the Minutes of the GAEC/RCA meeting concerning LEM Communications Subsystem Maintainability and Reliability Requirements. These are attached to the cover memo, LMO-550-323, J. Arleth, and L. McCoy, 10 June 1964, GAEC.

4.5.1.2 Vendor Meetings at GAEC (continued)

b. Reliability Models and Mission Profiles meeting held on 22 May 1964. This was an informal working meeting wherein RCA was briefed on the presently conceived communication mission profile and its reliability aspects. Means of increasing reliability by modal operation and possible reduction in duty cycle were discussed. In the event of modal failures the most acceptable lower modes of operation were examined.

c. Reliability meeting of June 16, 1964, three items of particular reliability interest discussed at this meeting were:

   1. An understanding of the GAEC part surface temperature philosophy and its implementation,
   2. The substantiation of reliability data, and
   3. Derating.

   The topic of derating was discussed extensively and RCA presented their policy. GAEC agreed to review it and give comments with possible alternates.

   Details of this meeting can be reviewed in LMM-180-229, 16 June 1964, GAEC.

4.5.1.3 VHF Transceiver Status

Breadboarding of many circuits and integration of some stages of the VHF set has been accomplished. Conceptual design has progressed to the stage of preliminary schematics. These have been shown to GAEC engineering by liaison engineers. These schematics show that RCA presently intends to design most of their high-frequency generation chains about transistorized harmonic generators. This approach will save weight since no idler circuitry is required. However, the use of proven transistors, careful derating and transient protection must now be assured in these circuits so as to obtain reliable operation.

The transmitter final output stage at present is shown to be three 2N3375 power transistors in parallel. This approach will also conserve power and weight compared to a varactor output. As forecast in earlier reports solid state approaches will cause the use of a number of state of the art components. The 2N3375 was just recently given its JEDEC number so it can not as yet rank with other proven transistors. Reliability will monitor these devices carefully and attempts will be made to see if a degradation detection technique could be incorporated into GSE checkout.

4.5.1.3 VHF Transceiver Status (continued)

Reliability will examine the transient exposures of these transistors during design and watch the thermal and design application margins. It will further insist upon both stress derating and observance of the thermal maximum for part surfaces.

4.5.2 Vendor Negotiations

Negotiations were held with the Rantec Corporation on the 11th and 12th of May 1964 for the VHF diplexer.

Rantec was questioned about possible detuning of the diplexer resulting from dimensional instability under thermal traverses. Their comment was that provided the diplexer received proper cold plate mounting there should be no problem. The writer requested the GAEC/RCA thermal and packaging engineers to follow this degradation aspect closely. Part feed throughs, plating and multipacting were also discussed with Rantec.

4.5.3 Antenna Status

4.5.3.1 The S-Band Erectable Antenna

On April 7, 1964, RCA demonstrated an erection of their full scale model erectable antenna (see reference (a)). As presently conceived their one shot spring design will open quite violently on the lunar surface (N.B. no air resistance and 1/6 g). This could cause human factors problems unless controllable restraint is placed on the spring action. Also, the antenna erecting mechanism, particularly the leaf springs, will require advanced QA techniques in order to avoid field reliability problems. These would be invoked during both development and fabrication in order to discover incipient mechanical weaknesses.

On 10 July 1964, a conceptual design review of this antenna was held at RCA, Moorestown, New Jersey (see reference (b)). To this date RCA still had made no human factors analyses nor had there been any effort made to determine astronaut mobility. The existence of a possible initial and degradation problem in the maintenance of reflector surface tolerance was discussed. Parts data, reliability and thermal analyses were not presented by RCA.

Although lacking this type of data RCA was granted the approval to build an experimental model by 15 September 1964. As

4.5.3.1 The S-Band Erectable Antenna (continued)

compensation for the inadequate data they were requested to build a model which simulated the deployment features of the final antenna rather than just electrical features.

4.5.3.2 S-Band Steerable Antenna

Proposals on the S-Band Antenna for subcontract to RCA were received from three of RCA's proposed subcontractors: (a) Dalmo Victor, (b) Avien and (c) Emerson.

These proposals were reviewed and evaluated by GAEC and RCA. Dalmo Victor was jointly selected on the basis of simplicity, reliability approach, design, planning and facilities.

The Dalmo Victor design proposal (see reference (c)) indicates a simple 26 inch parabaloid (dish) type antenna with crossed dipole disk feed which is more reliable than a complex array. The Earth detector consists of a Barnes infra red sensor mounted on the antenna reflector. Barnes is designing the IR sensor for the command module. The similarities of the LEM and CM sensors gives Barnes some prior conceptual reliability experience. However, an acute dissimilarity under study is the thermal aspect of lunar soak. Other Earth detectors were briefly considered during the proposal review but were discarded because of complexity.

The proposed antenna and its gimbaling are balanced by counterweights. It has limited rotation with stops at the designated end of travel. If LEM is so positioned that Earth is out of the range of antenna travel, then the antenna will hit the stops. This will put unnecessary strain on the antenna's structural supports and servo system. Possible solutions to this reliability problem are:

1. Decrease antenna dish mass by using a honeycomb type construction
2. Use center of gravity balancing of the antenna dish and gimbaling to eliminate counterweight necessity.
3. Usa a crank arm type of reciprocating action which alleviates the need of stops.

Items 1 and 2 are questionable due to thermal consideration (Reaction Control plume) and doubtful weight savings but both will receive some further study. Item 3 will be presented to RCA and Dalmo Victor for their consideration.

4.5.3.3 VHF and S-Band Omni and VHF Lunar Stay Antennas

To safeguard against the vibration stresses mentioned in the previous report a rigidizing and supporting structure about the VHF omni antenna is under design consideration. Should this seem insufficient then a radome may be considered.

Exploratory testing of all the subject antennas for the occurrence of multipacting is desirable. However, the operational testing of these large antenna structures in ultra high vacuums has developed into both a facilities and an absorbic materials search problem (see reference (d)). If a satisfactory solution is not found then a multipacting search in a bell jar should be run on all connectors, filters and matching networks associated with these antennas. Searching should be done running full RF power through these devices and using initiatory radioactive techniques.

4.5.4 S-Band Power Amplifier Status

4.5.4.1 Design Review of Amplifier

On June 25, 1964 a design review was held at the Space and Information Systems Division of the Raytheon Company. Minutes of the review appear in Raytheon's memo PA-20 of July 2, 1964.

Some of the prominent reliability action items discussed at the review follow.

1. Determine those performance monitoring features which should indicate amplitron degradation.
2. Determine which performance monitoring features could be attributable to malfunctions of both the amplifier and the external transmission system.
3. Examine amplitron tube removal to determine whether other modules are disturbed.
4. Examine the skin temperature of the 25W circulator dummy load when rated power is delivered at a 2 to 1 VSWR.
5. Study the failure modes of the proposed circulators and searchout their failure rates.
6. Validate or determine a failure rate for the amplitron tube and in the process search for its failure modes.

4.5.4.2 Amplitron Status

4.5.4.2.1 Intermittent Shorting Problem

The previous report discussed an intermittent shorting problem within the amplitron during testing at JPL. This problem was discussed with RCA reliability engineering during technical coordination meetings. RCA disclosed that Raytheon stated that a cathode seal failure was setting up conditions ideal for arcing. This was traced to inadequacies in the brazing bath process. This is a quality control problem which will definitely affect reliability and Raytheon is studying the process controls.

An allied problem is accurate centering of the cathode and/or sharp prominences and whiskering on the cathode. Careful tooling and burn off of such possible projections from the cathode surface were the solutions advanced by the tube design engineers.

4.5.4.2.2 Amplitron Life Testing

The lack of at least lower bound life test data appears to have been answered. In recent discussion with RCA engineers the writer has been informed of a Raytheon test plan which includes life testing of five tubes as well as stringent environmental and step stress testing on five others. This testing was to be negotiated into specifications. Documentary verification did not arrive in time for this writing. More details and documentation will be given in the following report.

4.5.5 Multipacting and Corona

This RF breakdown phenomenon is still under investigation since its occurrence can cause RF power losses from 50% to 90% (see reference (e)). Preventive measures are being taken by advising designers:

1. To minimize the use of microwave components having voids since these provide free electron paths.
2. To eliminate gaps and voids with dielectric filling if performance permits.
3. To procure pressurized microwave cavities where possible.
4. To keep alternate pressurized packaging designs in mind if multipacting develops downstream in the program.

Much difficulty is encountered in predicting this type of RF breakdown so that both specific components and systems must be considered as prospects. The empirical nature of the

4.5.5 Multipacting and Corona (continued)

the breakdown phenomenon requires that an exploratory testing program be initiated to search out all the possible components which could undergo multipacting. Searching may require a long period of time before breakdown hence, initiation techniques such as testing in the presence of radioactive isotopes are desirable (see reference (f)). Technical coordination with RCA is transpiring in order to define the possible problem areas.

4.5.6 Projected Effort

1. Continue work on a failure effects analysis now in progress.
2. Continue vendor documentation reviews.
3. Render technical assistance to the vendor by monitoring his efforts and maintaining technical coordination.
4. Study design review packages and attend scheduled design reviews.
5. Perform communication reliability system studies as the occasion arises.

4.5.7 Reference List

a. Arleth, J., RCA Erectable Antenna Conceptual Design, LAV-550-36, GAEC, April 8, 1964.

b. Alber, J., LEM Erectable Antenna Concept Design Review Meeting at RCA, Moorestown, New Jersey, LMO-380-245, GAEC 13 July 1964.

c. Technical Proposal for Lunar S-Band Steerable Antenna Assembly, R-2950-3429, Dalmo-Victor, Belmont, California, May 12, 1964.

d. Dudgeon, D., Grumman Inhouse Antenna Development Test Plans and Test Program Scheduling, LAV-380-86, GAEC, 15 May 1964.

e. Space Programs Summary No. 37-21, Volume 1, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, May 31, 1963.

f. Breeden, T. D., Preliminary Report on Cobalt 60 High Power Tests, Internal Memo, Astro-Electronics Division, Radio Corporation of America, Heightstown, New Jersey, July 2, 1963.

4.6 Environmental Control Subsystem

4.6.1 Summary

The following were the major areas of effort during the last report period:

a. Water Management Configuration Study (LED-550-27)

This study compared the existing water management with a proposed system. The study concluded that there was a reliability increase utilizing the proposed concept. This system will also save weight.

b. Success Path Study of the Related Functions of the EPS and ECS (LED-550-30)

This study showed the available alternate equipment paths resulting from failures of the equipment in the power generation section of the EPS and the oxygen section of the ECS.

c. Study of Space Radiator versus Water Boiler Cooling (LMO-540-336)

This study shows that an increase in reliability can be achieved and a potential weight saving effected with the space radiator concept.

4.6.2 Discussion

4.6.2.1 LEM Space Radiator Study

A space radiator/water boiler configuration versus a water evaporative thermal rejection system study is being conducted to determine the potential weight savings, reliability and over-all system effects.

LMO-540-336 is the report on this subject. This report indicates that there is a potential weight saving, and increase in reliability with the use of the space radiator configuration. The report recommends that a more detailed study be made to assess the value of an "all out" integrated system approach.

4.6.2.2 Path Study - Integrated EPS And ECS Common Equipment Paths

In order to achieve a functional path study for the LEM vehicle it became necessary to integrate the function of the Power Generating Section of the Electrical Power Subsystem and the Oxygen Section of Environmental Control Subsystem.

LED-550-30, "Mission Success Path Study of the Related Functions of the Electrical Power and Environmental Control Subsystem", provides the above information. This study takes into account the present grounds which will be used to determine the mission success and crew safety probabilities of this function.

4.6.2.3 Water Management Configuration Study

To provide the reliability support for the configuration change in the schematic drawing (LDW-330-6.000) for the ECS system, LED-550-27, "Environmental Control Subsystem Water Management Configuration Study", was provided. This study showed that the proposed concept characterized by a modular design, wherever the functions of water management are contained within one housing, increases reliability. The weight saving (in ascent) is effected by staging two of the three water tanks in the proposed concept, compared to the single-unstaged tank in the old concept.

4.6.3 Vendor Status

4.6.3.1 CO_2 Sensor Procurement

Pre-contract negotiations are presently underway with the Perkin-Elmer Corporation to determine if the Perkin-Elmer reliability plan has met the objectives of this LEM crew safety item.

Where reliability considerations were not adequate they are being changed to meet LEM reliability requirements.

4.6.3.2 Brushless DC Motor

Procurement of brushless DC montor's by Hamilton Standard is underway.

The basic objection to their use will be overcome if a "reliability test program" is successful in ascertaining:

1. distribution of failure with time
2. mode or modes of failure
3. verification that the motor is capable of performing under LEM environments.

LMO-550-196, "Proposed Reliability Test Program, Brushless DC Motor", is now being evaluated by NASA/MSC. Timely approval of go-ahead by NASA/MSC will allow this test program to be concurrent with ECS equipment build-up.

4.6.3.3 PLSS As A Back-Up For ECS

As a result of a coordination meeting with H.S.D. (reference H.S.D. LMM-1150-16) GAEC reliability requested H.S.D. to advise GAEC of the possible areas needing further study in order to consider the PLSS as a back-up for LEM/ECS.

H.S.D. presented the areas requiring study in their memorandum LVM-1150-0319. Summarizing their letter, the following area of study must be accomplished:

1. component life of PLSS items for extended LEM missions
2. method of replacement of LIOH cartridges in the PLSS (e.g., "Buddy System")
3. manner of conversion of LEM electrical supply (H.S.D. intends to use 17.5 volts for its PLSS)

These problems must be resolved and require further analyses by H.S.D..

4.6.3.4 Subcontractor Failure Mode And Effect Analyses

During the period the vendor failure mode and effect analysis work has materialized and there are about 40 preliminary and 11 detailed analyses submitted out of the approximated 70 items required.

4.6.3.5 Reliability Coordination

In order to integrate the reliability calculations between H.S.D. and GAEC coordination meetings were held. The following memorandums were prepared: LMO-550-333, "Report On Trip To H.S.D.", and LMO-550-334, "Minutes On Meeting 11 June 1964 - Between H.S.D. and GAEC Reliability." This provided a common basis between H.S.D. and GAEC for calculating ECS reliability. The GAEC specification for the ECS was also changed to specify the exact mission times for calculating reliability (see Section 3.)

4.7 Electrical Power Subsystem (EPS)

4.7.1 Summary

The major area of concentration during this report period has been in the power distribution area where a single General Purpose Inverter and a redundant inverter configuration were explored in great depth. This effort culminated in the July 2 presentation to NASA via conference call. Another area of activity was in sizing of an auxiliary battery for the three (3) fuel cell configuration.

4.7.2 Major Effort Anticipated In Next Quarter

1. Evaluate proposals and select vendors for:
   a. cryogenic relief valves
   b. reactant feed solenoid valves
   c. electrical connectors.
2. Continue effort on the failure mode and effect analysis.

4.7.3 Power Generation Subsystem

During this report period an initial study to generate the success paths uniting the concomitant functions of the ECS and the power generation section of the EPS has been completed. The general plan of this study began with an examination of the currently assumed mission objectives and the ground rules utilized to determine whether to continue or to abort the mission for various failure conditions. The complete study can be found in LED-550-30.

4.7.3 Power Generation Subsystem (continued)

An investigation into the weight penalty necessary to affect a significant gain in reliability by providing for micro-meteoroid shielding of the LEM system, and pressure vessels in particular was a major item of concern during this report period. LED-550-29 gives specific recommendations for marked reliability improvement of the supercritical reactant storage tanks by providing a minimum of micro-meteoroid shielding.

4.7.3.1 Fuel Cells

Pratt and Whitney Aircraft's Reliability Program Plan, PWA-2406, Revision B, dated 19 March 1964, was approved on 22 April 1964 as per LTX-170-816.

PWA submitted a revised failure mode and effect analysis and reliability data list as part of the May 1964 Monthly Progress Report, PWA-2429, Volume II, dated 10 May 1964.

4.7.3.2 Cryogenic Reactant Tanks

Garrett-Airesearch is now under contract and their Program Plan, SS-3090, dated 7 May 1964, was received 26 May 1964. The Program Plan, in general, covers the reliability requirements and may be considered acceptable with the resolution of the items enumerated in LMO-550-326, dated 15 June 1964.

4.7.3.3 Battery

The battery requirements for the LEM mission are in the progress of being finalized.

4.7.4 Electrical Distribution System

LED-550-26, dated 30 March 1964, presents the back-up reliability information for the LEM inverter finalization study presented to NASA on 29 January 1964. Additional information (paths including navigation and guidance function) was transmitted at the 2 July 1964 NASA presentation.

4.7.4.1 Inverter

The inverter procurement is pending final approval on the inverter configuration.

4.7.4.2 Portable Life Support System Battery Charger

Due to the change in the PLSS battery, a new specification is in the process of being drawn up.

4.8 Instrumentations Subsystem

4.8.1 Summary

Detailed information about the Scientific Instrumentation Section is still in the development stage and is therefore, not available.

A great part of the Operational Instrumentation Section equipment are in the stage of Specifications and Vendor Requirement preparation, except the PCMTEA which is subcontracted to Radiation, Inc. The GAEC Reliability analysis and estimates for the PCMTEA were reviewed and modified to reflect the effect of updated Failure Rate information replacing engineering best estimate information. These are stated in reference (a).

All other equipments have either completed Specifications or near completion, i.e., C&WEA and SEA, SCEA respectively.

Areas presenting problems are:

a. Field Effect Transistors, Pulse transformers, diodes for having doubtful reliability data and wire wound resistors whose resistance can vary with time.

b. Overall estimated PCM reliability is below that required by the specifications.

c. Lack of documented failure rates for the parts used in PCMTEA.

d. SEA, SCEA high reliability requirements imposed by the design.

e. Deficiency of failure rate documentation on integrated networks used in TE design.

4.8.2 Major Efforts Anticipated for Next Quarter

a. Review of past apportionment results for SEA and SCEA and prepare the reliability input to specifications.

b. Study of PCMTEA weak links and suggest modifications for the overall reliability improvement.

c. Search for and study interface problems of PCMTEA, displays and C&WEA and make recommendations for reliability improvement.

4.8.2 Major Efforts Anticipated for Next Quarter (continued)

d. Review failure rate lists and update all estimates of reference (a).

e. Update Specifications and Vendor Requirements.

f. Continue Failure Mode and Effect Analysis for Operational Instrumentation and Displays & Controls.

4.8.3 Discussion

Presently the estimates which appear in reference (a) show that the reliability goal of the PCM has not been met. It is the interest of these Reliability efforts to point out the weak links of the design and carry out configuration studies on possible design modifications, which will have an overall reliability improvement.

An attempt was made to use redundancy in the High Speed Gates, Programmer, Digital Multiplexer, Analog and Digital Gate Drivers of the PCM in order to determine the improvement in reliability. The results were discouraging. The power dissipation and weight increased considerably, and the reliability estimate improvement was negligible. However, efforts will continue in the area of failure rate selection and in the study of design redundancy within subassembly level.

4.8.4 Vendor Status

The design progresses with slight difficulties due to withholding of parts approval for lack of data and the introduction of design changes, such as the changing of the AC-DC power supply to DC-DC power supply in the PCM. Most of the parts specifications and Reliability Data Lists have been submitted by the Vendor. The review of these documents was completed and comments submitted.

Radiation, Inc., the PCM/TEA vendor has in general adhered to the Reliability Program.

No effort was made either in design configurations nor in failure rate selection to show their approach to reliability improvement of the PCMTEA.

4.8.4 Vendor Status (continued)

The Vendor did not respond to GAEC comments made on the reliability data lists and the progress reports.

It has been ascertained that the Vendor is willing to conform to the Reliability Program Plan agreed to and that the GAEC exception stated above will be satisfied in the near future.

Reference: (a) LED-550-16 "Reliability Analysis of Instrumentations Subsystem".

4.8.5 Displays & Controls

Specification and Vendor Requirements have been prepared for the Electronic Clock and the Event Timer.

Proposals submitted by Bulova and Gibbs were reviewed and evaluated, Bulova was selected as a vendor for the items mentioned above.

Vendor negotiations were attended, as reflected in references (a) and (b), among the items followed up in the Displays and Controls S/S activities.

Specifications and Vendor Requirements for the "C&WEA Displays" are in preparation.

References: (a) LMO-550-265 "Proposal Clarification Request"
(b) LAV-350-37 "Bulova Watch Co. AVO dated 15 June 1964"

4.9 Structures Subsystem

4.9.1 Summary of Subsystem Effort During This Period

1. Stage Separation System and Components were studied (reference LMO-390-188)
2. Selection of one type of mechanically operated blind rivet (reference LMO-550-282)
3. Study on effects of docking requirements on LEM configuration (reference LMO-540-285)

4.9.1 Summary of Subsystem Effort During This Period (continued)

4. Failure Mode and Effect Analysis has been started.
5. Micrometeoroid Protection Study (reference LED-550-29)
6. Monitored Descent Propellant Tank Vendor (reference LAV-280-54)
7. Input in selection of Ascent Propellant Tank Vendor (reference LMO-550-260)

4.9.2 Major Effort Anticipated for Next Quarter

1. Work will be performed on evaluating the Ascent-Descent stage separation system components.
2. The Failure Mode and Effect Analysis effort will be continued.
3. Monitoring of Vendor effort will be continued.

4.9.3 Discussion

1. Stage Separation System and Components

   Conceptual design reviews were conducted with design groups to evaluate the possible usage of a MDF (Mild Detonating Fuse) Stage Separation System, as opposed to the electrically initiated hot wire system. Possible configurations were studied and feasibility tests performed. It was established that the LEM would use the electrically initiated system (reference NASA-GAEC pyrotechnic meeting, Houston, April 8,9, 1964). The MDF system would require too much development time.

   Interstage electrical umbilical connectors are being studied and proposals evaluated. Various methods of separating the interstage umbilical such as; mechanical, pyrotechnic operated guillotine, shaped charge, are being studied. Result of propress to date are contained in LMO-390-188 and soon to be released LMO-390-231.

   Interstage fluid disconnects are being studied. Specifications have been prepared and reviewed. Proposals are being evaluated. Revisions to the specification are in process to reflect latest information, such as; misalignment tolerances both angular and linear due to asymmetrical stage separation, valve sequencing, etc.

4.9.3 Discussion (continued)

2. Reliability of Blind Rivets

   There are in general two types of mechanically operated blind rivets. A study of these types was conducted with a definite choice being made for one particular type. Details are contained in LMO-550-282.

3. Docking Requirements

   A study on the effects of docking requirements on the LEM configuration was conducted. Reliability inputs for the three configurations studied are contained in LMO-540-285, dated 15 April 1964.

4. Failure Mode and Effect Analysis

   FMEA has been started. This will cover areas such as: Docking, Landing Gear, Hatches, Structure and Pyrotechnic Systems. The latter include: Ascent-Descent Stage Separation System; Landing Gear Extension: Antenna Erection; Descent, Ascent, and Reaction Control Engine Pressurization.

5. Micrometeoroid Protection Study

   The purpose of this study was to recommend how much micrometeoroid shielding should be added to LEM, where it should be allocated and to determine the probability of not having a catastrophe due to meteoroid bombardment. For details see LED-550-29, dated 11 May 1964.

4.9.4 Vendor Status

1. Descent Propellant Tank Vendor

   Monitoring of the Allison reliability effort continued. Major items were, approval of the program plan and receipt of monthly progress reports.

2. Ascent Propellant Tank Vendor

   Proposals from vendors were evaluated and Aerojet was selected.

References

a. LMO-550-282, 28 April 1964 "Use of Blind Rivets".

b. LMO-390-188, 7 May 1964. "Interstage Electrical Umbilical".

4.9.4 Vendor Status (continued)

References (continued)

c. LMO-540-285, 15 April 1964. "Effects of Docking Requirements on the LEM Configuration".

4.10 Crew Provisions Subsystem

4.10.1 Summary of Subsystem Effort During This Period

1. Design Reviews continued
2. Document Review
3. Indicator Tube Study
4. Started Failure Mode and Effect Analysis

4.10.2 Major Efforts Anticipated for Next Quarter

1. The Failure Mode and Effect Analysis effort will be continued.
2. The crew support and restraint system design and test will be monitored.

4.10.3 Discussion

1. Design Reviews

Design reviews for various systems were conducted. As a result of these design reviews revisions such as the following are planned:

a. For the astronaut's descent-ascent system which is basically a ladder; potential suit and toe catching protrusions on the steps, railings and railing supports are being redesigned.

b. For the Food and Water System; placement of expiration date on the package; and removal of sharp corners.

4.10.3 Discussion (continued)

1. Design Reviews (continued)

   c. For Lighting and Displays; revision of switch-name plate locations to minimize chance of selecting wrong switch.

2. Document Review

   In regard to the Back Pack drawing, a suggested change is generous rounding of the Back Pack corners to permit easier astronaut ingress and egress. In addition, rounding of the corners of the Back Pack would better permit the astronaut to get up from a prone position on his back, should he ever attain this position, (for example on the lunar surface). During this period, effort has been expended in the review and revision of equipment criticality ratings (see reference LMO-550-23). This reflects the latest criticality ratings, and is used to determine the number of equipments to be utilized for test purposes.

3. Indicator Tubes

   A study was performed on the possible use of Nixie Indicator Tubes for displays as opposed to the more common filament type. Nixie tubes are gas filled cold cathode glow discharge display indicators. It was felt that the life of the Nixie tube was the same order of magnitude, but the Nixie required the addition of a 28 to 170 volt DC converter plus more circuitry. It was therefore, concluded that the reliability of the Nixie system would be lower than the simpler filament system.

4. Failure Mode and Effect Analysis

   Failure Mode and Effect Analysis has been started. This will cover areas such as; Crew Support and Restraint, Usage of Pressure Suit, Wast Management, Food and Water, Germicide Tanks, Lighting Systems, Ingress and Egress, Descent-Ascent System LEM-Lunar Surface and Vomitus Management.

5.0 RELIABILITY ASSURANCE PROGRAM

5.1 Summary Of Activities

Activities during the last quarter were principally routine test planning, monitoring activities and vendor negotiations. The results of these activities are reported in Table 5-0, Test Program Progress. Specific details for each subsystem are provided in the text of this report.

5.1.1 Amendments To Specifications

During the reporting period a procedure was established in which the specification amendments from Systems Test, Structural Analysis, and Reliability were reviewed, coordinated and submitted to the subsystem group. The responsibility for implementing this procedure rests with the Reliability group since all specifications must be signed off by Reliability before they are issued. When the specification is submitted to Reliability for signature the Systems Engineering inputs (Systems Test, Structural Analysis, and Reliability) are reviewed for accuracy, completeness and technical content before the specification is signed off.

5.1.2 Test Identification

A transmittal sheet for the Test Identification Section of the LEM Reliability Computer Program (LRCP) has been fully developed. Use of the transmittal sheet serves the following purposes:

1. Written record of basic qualitative data concerning a specific test. Detailed information can be obtained from the test plan or report if needed.
2. The transmittal sheet is the most preferable method of transferring engineering data onto IBM punch cards because of the increased efficiency in key punch operation.
3. The transmittal sheet facilitates the engineering discipline of recording data concerning both planned and operating tests.

The integrated characteristics of the LRCP allows cross referencing between the various computer sections such as Failure Reporting and Analysis, Parts Control and Test Identification.

TABLE 5.0

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Communications				LPL-6070-1	Program Plan
S-Band Steerable Antenna	CB	Vendor to RCA		Proposals	Dalmo Victor Avien, Emerson
S-Band Erectable Antenna	CN	RCA	DF		
S-Band Transceiver	CN	RCA - Motorola	DF		
S-Band Power Amp.	CN	RCA - Raytheon	DF	LEM 4140-5.2	Test Plan for DF Tests on Power Amplifier.
S-Band Diplexer	CN	RCA	DF		
VHF Transceiver	CN	RCA	DF		

LEGEND

C - Completed
CB - Completed, Bidder Proposals Under Evaluation
CV - Completed, Vendor Negotiations in Progress
CN - Completed and Negotiated
DF - Design Feasibility
NA - Not Applicable
UP - Under Preparation
DV - Design Verification
IP - In Progress

* Where LSP is used, procurement spec. contains Quality Assurance Provisions but no test plans have been formulated.

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Communications (continued)					
Premodulation Processor	CN	RCA - Collins	DF		
Audio Center	CN	RCA - Collins	DF		
VHF Diplexer	CN	Rantec	DF	LSP-380-3A *	VHF Diplexer
Manual Coaxial RF Switch	CB			LSP-380-7A	Manual Coaxial RF Switch
RF Cables & RF Connectors	UP				
VHF In-Flight Antenna	C		DF		
S-Band In-Flight Antenna	UP		DF		
VHF Lunar Stay Antenna	UP				
Crew Provisions					
Incandescent Lamps	UP				
E. L. Lamps	UP				
Lighting	UP		CP	LTP-907-11001	Vibration Test of Display Comp.
Seats			DF	LTP-907-17001	Shock Test of Crew Restraint Assembly
Support & Restraint			IP	LTP-907-14001	Plan for Shock Test of Crew in LEM Crew station.

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Controls & Displays					
Display Panel			C	LTR-908-11001	Results of Vibration Test of Display Components.
Instrumentation	CV	Bendix		LSP-350-306	Thrust-to-Weight Ratio Indicator
Instrumentation	CV	Bulova		LSP-350-304	Electronic Event Timer
Instrumentation	C	UP		LSP-350-307	Altitude and Range Indicator
Instrumentation	C	UP		LSP-350-809	Caution and Warning Displays
Instrumentation	C	CV		LSP-350-801	D'Arsonval Meters
Instrumentation	CV	Bulova		LSP-350-601	Electronic Clock
Electrical Power Subsystem					
Fuel Cell Assembly	CN	Pratt & Whitney		PWA-2402-B- (LPL-1160-3B)	Test Plan for LEM Fuel Cell Assembly(Rev.B)
				PWA-2426 (LTP-1160-4)	LEM PC6A-1 Fuel Cell Assembly Experimental Model-Detail Test Plan.

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Electrical Power Subsystem					
Fuel Cell Assembly (continued)				PWA-2413 Rev. A (LTP-1160-2A)	LEM RC6A-1 Fuel Cell Assembly Experimental Model End-Item Test and Inspection Procedures.
				PWA-2427 (LPR-1160-10)	LEM Fuel Cell Assembly Monthly Progress Report for the Period Ending 15 March '64
				PWA-2429 (LPR-1160-11)	LEM Fuel Cell Assembly Monthly Progress Report for the Period Ending 15 April 1964
				PWA-2428 (LED-11603)	LEM PC6A-1 Fuel Cell Assembly Experimental Model, GSE Study.
				PWA-2431 (LRP-1160-12)	LEM Fuel Cell Assembly, Monthly Progress Report Period Ending 15 May 1964

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed: Number	Documents Reviewed: Title
Electrical Power Subsystem					
FCA Components			DF		
Cryogenic H_2 & O_2 Storage & Supply Subsection					
Tank Assemblies	CN	AiResearch		RPT# SS-3117 (LLI-5050-1)	Specification Tree, AiReserach Furnished Equipment, LEM Cryogenic Tankage Program
				SS-3090	Program Plan, Tank Assembly, Cryogenic Storage & Supply. Electrical Power Subsystem for the Lunar Excursion Module.
				SS-3136 (LPR-5050-1)	1st Monthly Progress Report, Tank Assembly Cryogenic Storage & Supply, Electrical Power Subsystem for the LEM.
Cryogenic Reactant Control Components					
Check Valve	CB				
Solenoid Valve	CB				
Relief Valve	CB				
I/S Quick Disconnect	CB				
Fill & Vent Valve	UP				

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Electrical Power Subsystem (continued)					
Battery	CV	Yardney			
Battery Charger	CB				
Power Distribution Section					
Inverter	CB				
Electrical/Mechanical Relays	UP				
Electrical Connectors, Rectangular	UP				
Electrical Connectors, Circular	CB				
Umbilicals	UP				
Relays	UP				
Circuit Breakers	UP				
Cable & Wire	UP				
Lighting	UP				

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed Number	Documents Reviewed Title
Environmental Control Subsystem				LPL-330-2	Test Plan for the Development Tests of the Heat Transport & Water Management Sections of the LEM ECS
				LPL-330-3	Test Plan for the Development Tests of the Oxygen Supply Section of the LEM ECS
Assemblies & Components (Atmosphere Revitalization Section, Oxygen Supply & Cabin Pressure Control Section, Heat Transport Section, Water Management Section)	CN	Hamilton Standard		SVHSER 2807-2 (LED-1150-16)	Lunar Excursion Module Environmental Control & Life Support Subsystem, Quarterly Design Report for the Period of October 22, 1963 thru December 31, 1963.
				SVHSER 2790-7 (LPR 1150-14)	Progress Report for the Month of February 1964, LEM Environmental Control & Life Support Subsystem

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Environment Control Subsystem (continued)					
Assemblies & Components (continued)				SVHSER 2790-8 (LPR-1150-15)	Progress Report for the Month of March 1964, LEM Environmental Control and Life Support Subsystem
				SVHSER 2790-9 (LPR-1150-16)	Progress Report for the Month of April 1964, LEM Environmental Control and Life Support Subsystem
				Test Plan No. 2000 (LTP-1150-1)	Component Development, LEM Suit Temperature Control Valve, Item 208
				SVHSER 2790-10 (LPR-1150-17)	Progress Report for the Month of May 1964, LEM Environmental Control and Life Support Subsystem

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Environmental Control Subsystem (continued)					
Cryogenic Oxygen Storage Section (see Electrical Power Subsystem)					
Cold Plate Section	UP				
CO_2 Sensor	CV	Perkin-Elmer			
Instrumentation					
PCM/TEA	CN	Radiation, Inc.	DF	LPR-1480-4	Design Report No. 1
				LLI-1480-2A	Drawing Spec. & Documentation List
				LPC-1480-3	Configuration Control Procedures
				LPC-1480-1	Mechanical Feasibility Test Procedure
				LPC-1480-2	Thermal Feasibility Test Procedure
				LTR-1480-1	Detail Test Report of the Exploratory Vibration Tests

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Instrumentation (continued)					
C&WEA	CB		NS		
OBCEA	UP		NS		
SCEA	UP		NS		
DSEA	UP		NS		
Sensors	UP		NS		
Mechanical Design Subsystem					
EED Subsection				LTP-320-1	Summary Test Plan for Development Testing of LEM Electro Explosive Devices.
				NAA-MC 453-0009B	Procurement Spec. for Electrical Hotwire Initiator.
			DF	LTP-922-16001	Environmental Development Tests on TM-4 Separation Stage Devices.
			DF	LTP-320-4	LEM Landing Gear Uplock-Devices Design Feasibility Test Plan

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Navigation & Guidance					
Rendezvous Radar	CN	RCA	DF		
Transponder	CN	RCA	DF		
Landing Radar	CN	Ryan	DF	LPD-(P)-3600	Landing Radar (N&G) Procurement
Radar (General)		RCA		LPR-(P)-3100-1	Quarterly Design Report, 1st
				LMR-(P)-3100-4	Monthly Status Report, 4th
				LMR-(P)-3100-5	Monthly Status Report, 5th
				LMR-(P)-3100-6	Monthly Status Report, 6th
Propulsion					
Ascent Engine	CN	Bell	DV	LPR-2000-35	Monthly Progress Report #9
				LED-2000-8A	Engine Characteristics Report
				LPR-2000-41	Monthly Progress Report #11

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Propulsion (continued)					
Ascent Engine (continued)				LPR-2000-39	Monthly Progress Report #10
				8258-932004	Reliability Assurance Test Plan and Failure Mode Prediction Analysis
				8258-B4-7209	Filter Specification
				8258-928001	Acceptance Test Plan
					Development Valve Package Assembly Test Plan
Pressurization					
Press.Reduc. Valve	CN	Sterer			
Sol. Latch. Valve	CV				
Quad. Check Valve	CV				
Coupl. He Fill Disct.	CV				
Coupl. Test Point Disconnect	CV				
Helium Tank	C				
Helium Filter	CV				
Pres.Relief & Burst Disc.	CV				

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Propulsion (continued)					
Pressurization (continued)					
Expl. Oper. Va 3/8	CV				
Feed					
Coupling (Fuel)	CV				
Coupling (Oxidizer)	CV				
Coupl. (Fuel) Fill&Vent 3/8	CV				
Coupl. (Fuel) Fill&Vent $\frac{1}{4}$	CV				
Coupl. (Oxid.) Fill&Vent 3/8	CV				
Coupl. (Oxid.) Fill&Vent $\frac{1}{4}$	CV				
Propellant Quantity Gaging	UP				
Descent Engine					
Fixed Injector (Helium Injection)	CN	Rocketdyne	DV	R5205-11	Monthly Progress Report
				R5205-12	Monthly Progress Report
				R5205-13	Monthly Progress Report
				LTP-1050-3	Milestone No. 18 Performance
				LTP-1050-4	Milestone No. 21 Performance
				LTP-1050-5	Milestone No. 22 Performance

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Propulsion (continued)					
Descent Engine (continued)					
Variable Injector (Mechanically Throttle-able)	CN	STL	DV	LPR-1100-56	Monthly Progress Report
				LPR-1100-57	Monthly Progress Report
				LPR-1100-59	Monthly Progress Report
				LPR-1100-66	Monthly Progress Report
				LTP-1100-3	Injector Assembly Rel. Assur.Test Plan
				LTP-1100-9	Thrust Mount & Gimbal Assembly Reliability Assurance Test Plan
				LED-1100-95	Electrical Package Design
				8430-6016	Performance of the VETS 005 Engine

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed: Number	Documents Reviewed: Title
Propulsion (continued					
Descent Engine (continued)					
Variable Injector (continued)				EQ1-87	Engine Component Spec.
				9733 4-64-40	Test Report, Flow Control Va.
				9733 4-64-34	Test Report, Flow Control Va.
				LTP-1100-4	Qualification Test Plan, Engine Shipping Container
				LTR-1100-3	Feasibility Ablative Material Evaluation
				LTR-1100-1	Subscale Nozzle Extension Tests
				LTP-1100-7	Prototype Head End Assembly Engine Test Plan
				LPL-1100-9	Throttle Actuator, Acceptance Test Plan

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Propulsion (continued)					
Descent Engine Components					
Pressurization					
He. Press Tanks	C				
He. Filter	CV				
Coupl.He.Fill & Disct.	CV				
Coupl. Test Point Disct.	CV				
Latch. Sol. Va.	CV				
Press. Reducer Va.	CN	Sterer			
Quad. Check Valve	CV				
Pres. Relief & Burst Disc.	CV				
Expl. Oper. Va. $\frac{1}{2}''$	CV				
Feed					
Coupling (Fuel)	CV				
Coupling (Oxidizer)	CV				
Coupl.(Fuel)Fill&Vent 3/8	CV				
Coupl.(Fuel)Fill&Vent $\frac{1}{2}$	CV				
Coupl.(Oxid)Fill&Vent 3/8	CV				
Coupl.(Oxid)Fill&Vent $\frac{1}{2}$	CV				
Filter (Oxidizer)	CV				
Filter (Fuel)	CV				
Propellant Quantity Gaging	UP				

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Reaction Control					
Propellant System & TCA	CN	Marquardt	DF	L1001-8 L1001-9 L1001-10	TMC Monthly Progress Reports
				LMO-550-277	Review of TMC Spec. for the Main Line Valve (EPS 157)
				LMO-550-287	Review of TMC Spec. for the Cluster Isolation Valve (EPS 159)
Propellant Tanks	CN	Bell	DF		
RCS Components					
Helium Press.					
Tank	CV	Airite			
Expl. Oper. Valve	C	*Pelmec			
Filter	CB				
Sol.Latch Valve	CV	*Sargent			
Press. Regulator	CB	*Fairchild			
Quad. Check Valve	CV	*Accessory Prod.			
Relief Valve	CV	*Calmec			
Coupl. Fill Disconnect	CV	*On-Mark			

* Common Usage per SLE-22-455, dated 29 October 1963

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Reaction Control (continued)					
Propellant Feed					
Coupl. Fill Drain	CV	*J. C. Carter			
Sol. Latch Valve	CV	Parker			
Filter	CV	Purolator			
* Common Usage per SLE-22-455, dated 29 October 1963					
Stabilization & Control					
Rate Gyro	CN	Kearfott	DF	LPL-1040-1 thru LPL-1040-8	LEM Rate Gyro Assembly Program Plan
Attitude & Translation Control	CN	RCA	UP		ATCA Program Plan
Gimbal Drive Actuator	CV	AiResearch			
Descent Engine Control	C				
Attitude Controller	C				
Translation Controller	C				
Attitude Reference	CB				
Abort Programmer	C				
In-Flight Monitor	UP				

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed: Number	Documents Reviewed: Title
Vehicle Design & Integration					
Ascent Engine Tanks	CN	Aerojet	UP		
Descent Stage Tanks	CN	Aerojet	CN	LTP-905-14002	Descent Stage Tank Tests.
		Allison	UP	LPC-2800-3	Static Load-Baffle Subassembly
		Allison	UP	LTP-2800-1	Detail Test Plan to Perform Vibration Test on Baffle Sub-assembly
		Allison	UP	EDI-R-274	Acceptance Test - Descent Stage Propellant Tank Assembly.
Ascent Stage Structure			IP	LTP-905-13002	Test Plan for the LEM Ascent Stage Sealant Program
Descent Stage Structure			IP	LTP-905-14003	Static Test of Shear Panel.

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed: Number	Documents Reviewed: Title
Vehicle Design & Integration (continued)					
Landing Gear Devel. Test			C	LTP-904-16001	Landing Gear Stability Drop Test Plan
			C	LTP-904-10001	Feasibility Test of Pelmec Bolt
			DF	LTP-904-16001	Test on Landing Gear Cantilever Strut.
			DF	LTP-904-10001	Honeycomb Cartridge Landing Gear Test
			DV	LTR-904-10001	Test on Landing Gear Primary Strut Assembly Test
			DF	LTR-904-13001	Plan for the Landing Gear Stability Drop Test.
Windows			C	LTP-914013001	Screening Test of LEM Window Materials Report

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Ground Support Equipment					
Test	C	UP		LSP-430-82720	Mass Spectrometer Leak Detector Assembly (Helium)
Test	C	UP		LSP-430-8170 LVR-430-8170	Mass Spectrometer Leak Detector Assembly (Helium or Hydrogen)
Test	C	UP		LSP-430-54600 LVR-430-54600	Freon Supply Unit Assembly
Test	C	UP		LSP-430-52120 LVR-430-52120	Gaseous Oxygen Component Test Stand Assembly
Test	C	UP		LSP-430-54200	Gaseous Oxygen Transfer Unit
Test	C	UP		LSP-430-6350	Referee Oxidizer Mobile Propellant Conditioning Unit
Test	C	UP		LSP-430-6340	Referee Fuel Mobile Propellant Conditioning Unit

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Ground Support Equipment (continued)					
Test	C	UP		LSP-430-62180	Reaction Control Subsystem Checkout Cart
Test	C	UP		LSP-410-3825	Radar Signal Generating Equipment (Landing and Rendezvous)
Test	C	UP		LSP-430-54400 LVR-430-54400	Cabin Leakage Test Unit Assembly
Test	C	UP		LSP-430-52160 LVR-430-52160	Water Components Test Stand
Test	C	UP		LSP-430-14000	LEM Fluid System Ground Support Equipment, General Spec.
Test	C	UP		LSP-410-12000	LEM GSE Electronic Equipment, General Specification.
Test	C	UP		LSP-430-52210 LVR-430-52210	Water/Glycol Component Test Stand Assembly
Test	C	UP		LSP-430-54700 LVR-430-54700	Water/Glycol Trim Control Unit Assembly

TABLE 5.0 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor	Test Status	Documents Reviewed	
				Number	Title
Ground Support Equipment (continued)					
Test	C	UP		LSP-420-13000	LEM & Ground Support Handling & Transportation Equipment, General Specification
Test	C	UP		LSP-410-7500A Amend. #1	Pulse Code Modulation and Timing Assembly
Test	C	UP		LSP-420-63320	Force Measurement Section
Test	C	UP		LSP-430-64420	Propellant Loading Control Assembly
Test	C	UP		L1S-430-18001	GSE Fluid Distribution System Piping Criteria
System Test			UP	LTP-940-00000	Preliminary LTA-10 Test Plan
Flight Development			UP	LTP-610-3	LEM Pre-Launch Checkout Plan (Test & Operations Plan)

5.1.2 Test Identification (continued)

Only a minimum amount of data, i.e., Part Number and Test Plan Number, is needed to establish records concerning a particular test in the LRCP. Since the transmittal sheets are printed on specially prepared vellum, it is relatively easy to add, delete or change data in connection with specific tests. At present, production data is being prepared on transmittal sheets in anticipation of the completion of the LRCP.

A reduced size sample of the transmittal sheet is given in the Appendix A.

5.2 Subsystem Program Progress

5.2.1 Descent Propulsion

5.2.1.1 Descent Engine - Rocketdyne

Major effort during the past quarter was devoted to selection of the final injector orifice pattern design. Selection was based on over 47 workhorse injector and thrust chamber tests run during this period alone. The type 05 pattern was selected as the basic LEM injector (triplet, F-O-F). Variations of this basic design are the 5C (8% film coolant), 5D (5% film coolant) and type 22 (basic 05 pattern, F-O-F, except outer 3 rings have 297 patterns instead of 72). Investigation of each variation will continue. The 05 pattern has yielded a C* efficiency of 98% with an allowable throat erosion and zero P_c "pop" frequency.

Major problem areas which are being investigated are:

1. Baffle burning problem
2. Thrust chamber gauges under the baffles
3. Self induced popping during throttling without helium.

5.2.1.2 Descent Engine - Space Technology Labs

Two Reliability Assurance Test Plans have been received from STL.

1. LEM Descent Engine Injector Assembly Reliability Assurance Test Plan STL #8438-6108-SU000 (GAEC LTP-1100-3).

5.2.1.2 Descent Engine - Space Technology Labs (continued)

2. LEM Descent Engine Thrust Mount and Gimbal Assembly Reliability Assurance Test Plan STL #8438-6118-SU000 (GAEC 1100-9).

The first test plan was reviewed and found to conform to the general Reliability Assurance intent. Mission Simulation, Check of Qualification Test Levels and Stress-to-Failure Tests were developed completely in line with GAEC intent. However, since mission simulation did not include a "hot firing" to represent the descent phase of the mission, the test plan was not approved. The failure mode prediction analysis indicates failure of the bearings or flexure as being most critical, and for this reason, STL did not incorporate a "hot firing". GAEC is now awaiting STL formal comments regarding the disapproval (Ref. LMO-550-349).

The second test plan received is still being reviewed.

5.2.1.3 Descent Propulsion Components

Vendor proposals for the design and manufacture of components for the descent pressurization and feed systems have been evaluated and rated by a team of GAEC engineering personnel. Preliminary negotiations with selected vendors were also completed and quotes on the Test Program have been evaluated. A purchase order was issued to Sterer Engineering Mfg. Co. of Los Angeles, California to supply the Helium Pressure Reducing Valve (LSC-270-816) for the pressurization system.

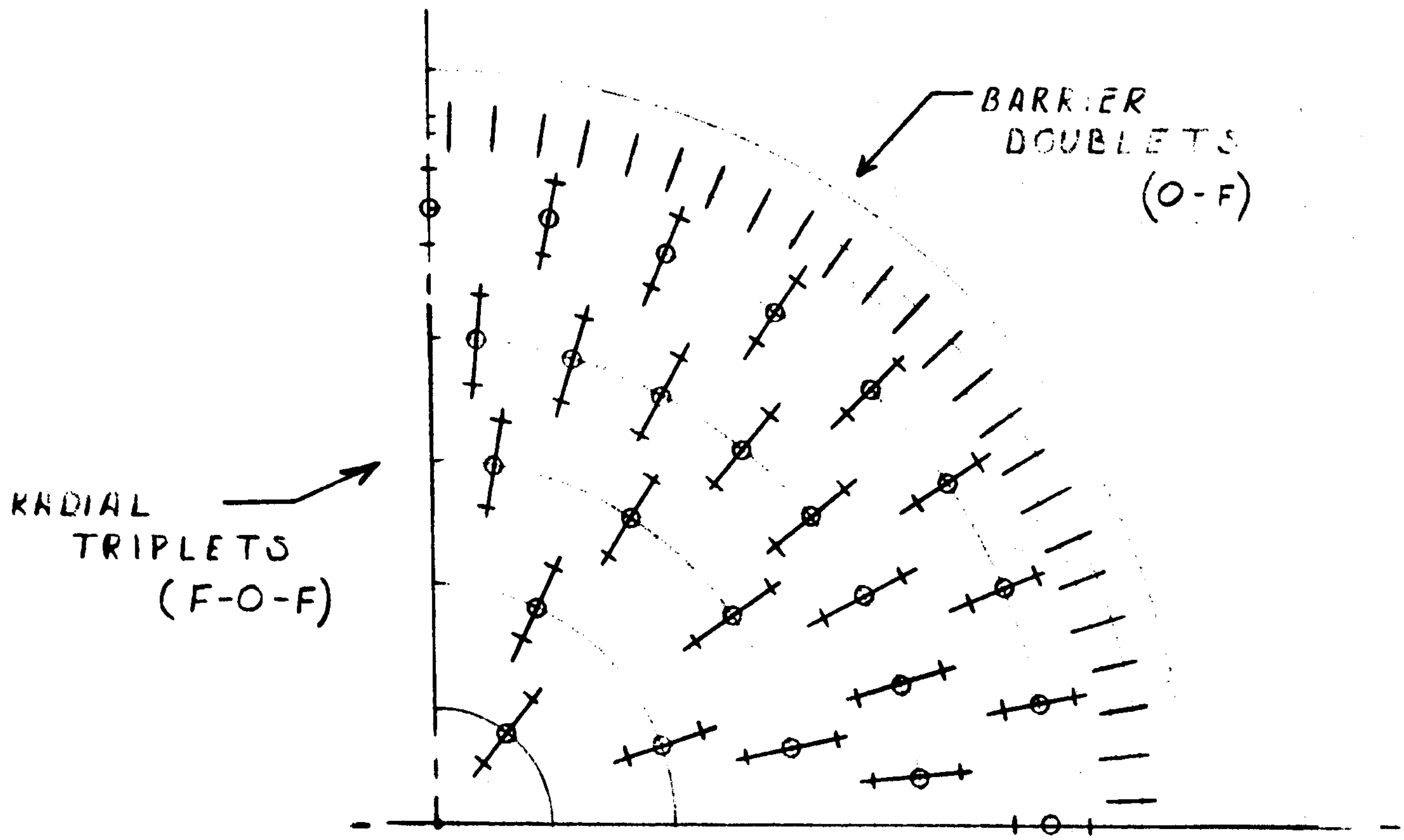
The status of the descent propulsion components is tabulated in Table 5.0 (Test Program Progress). As purchase orders are issued, a list of accepted vendors will be included in the next report.

5.2.2 Ascent Propulsion

5.2.2.1 Ascent Engine - Bell

Of major importance during this past quarter was the start of testing at AEDC. For the first time a full 40:1 chamber was fired. Firing schedule simulated a typical engine life cycle consisting of a 10 second firing, a 380 second firing, and finally a 15 second firing. End of run specific impulse for tests using the HITCO chamber met specification requirements

~~CONFIDENTIAL~~



LAYOUT - TYPE B3 INJECTOR

Figure 5-1

~~CONFIDENTIAL~~

5.2.2.1 Ascent Engine - Bell (continued)

and on the basis of these tests, HITCO has been selected as the final ablative supplier.

Along with this accomplishment Bell testing has yielded results which has resolved the injector problem which was causing undercutting of the ablative thrust chambers at the injector end of the chamber section. Injector/ablator compatibility test results show the radial pattern type B injector to be most promising. This pattern is a basic radial triplet pattern with an outer ring of barrier doublets. Figure 5-1 is a layout showing a typical B type injector layout. Bell is continuing tests to finalize this design and will vary the number of barrier doublets until best performance is achieved.

5.2.2.2 Ascent Propulsion Component

Preliminary negotiations for the design and manufacture of ascent propulsion components for the pressurization and feed systems have been completed between GAEC and selected vendors and quotes on the Test Program have been evaluated. A purchase order was issued to Sterer Engineering Mfg. Co. of Los Angeles, California to supply the Helium Pressure Reducing Valve (LSC-270-715) for the pressurization system. The status of the ascent propulsion components is tabulated in Table 5.0 (Test Program Progress).

As purchase orders are issued, a list of accepted vendors will be included in the next report.

5.2.3 Reaction Control Subsystem

5.2.3.1 Propellant System and Thrust Chamber Assembly - Marquardt

Testing on the workhorse cluster in Cell 9 was concluded during the last quarter. Test results indicate the line dynamics influence pulse performance and reproducibility increases with pulse width and off time. Further cluster testing has been curtailed until a final S/M engine design has been frozen.

At the present time the S/M engine design consists of a two piece combustion chamber, joined mechanically. Major problem areas of the S/M engine which must be resolved are (1) high chamber pressure spikes resulting in shattering of the engine, and (2) passive thermal management. Testing of various, proposed design changes (pre-mix chamber, valve timing, increased wall thickness...etc.) are presently being conducted to determine solutions to the spiking problem.

5.2.3.1 Propellant System and Thrust Chamber Assembly-Marquardt (cont'd)

A decision was made to remove the propellant burst disc and screen assembly. The decision was arrived at after reviewing the design and system operation requirements of the RCS. Marquardt was notified to stop all effort associated with the propellant burst disc and screen assembly. Marquardt was also notified that the main line shut-off valve would now be common usage with the Grumman supplied ascent interconnect valve. TMC was relieved of any responsibility for the procurement of the main line shut-off valve.

5.2.3.2 RCS Propellant Tankage - Bell

The preliminary design review was held at Bell on May 21 and 22. Agenda items were:

1. Test Plans
2. Reliability
3. Stress Analysis
4. Weight & Volume Calculations
5. Vibration Parameters

It was agreed during the discussion of the test plans that during diffuser tube feasibility testing the test levels would be increased to 1.5 of qualification levels to determine point of failure. During the feasibility test phase one oxidizer tank will be vibrated at ambient temperature and pressure, fully loaded, to check for critical buckling.

Amendment No. 1 to the specification was submitted to Bell for review and SCP action. The amendment contains requirements for using actual propellants during slosh, expulsion and volume verification tests.

Bell is experiencing excessive random bladder failures on the Apollo propellant tanks. Development testing has been stopped pending a full investigation into the cause of the failures. Preliminary results indicate one possible cause is permeation of the propellants through the 3 mil bladders causing separation among the plys. Further laboratory testing will be required before the exact cause of failure can be determined.

5.2.3.3 RCS Helium and Propellant Components

Table 5.0 lists the status of all the RCS components. Proposals have been received and evaluated for all the helium and propellant components. Vendor negotiations are in process for

5.2.3.3 RCS Helium and Propellant Components (continued)

all the components except the propellant filter and explosive valve. Recent changes have occurred in the RCS components as directed by NASA letter EP-4-10-64-213 dated 19 May 1964 which affects the procurement document status. GAEC was considering a dual initiator explosive valve. NASA has directed that GAEC use two single initiator explosive valves in parallel. This direction will require revision to the design control specification.

NASA has directed that the propellant manifold crossfeed valves be solenoid operated instead of explosive actuated. The design control specification for the explosively actuated crossfeed valve has been cancelled. The crossfeed valve will now use the same valve as the ascent interconnect valve.

The propellant ground test coupling has been eliminated. A fill-drain coupling will be used downstream of the propellant main feed shut-off valves to service the fuel manifold.

5.2.4 Stabilization and Control Subsystem

5.2.4.1 Rate Gyro Assembly (RGA) - Kearfott

Program Plan for the RGA, submitted to Grumman for approval, was reviewed by Reliability and comments are contained in LMO-550-317. The RGA is in the Design Feasibility phase of the Development Program and Test Plans are now being prepared. The Monthly Progress Reports indicate that the program is about two (2) weeks behind schedule, however, Kearfott expresses confidence that they will be back on schedule within the next few months.

5.2.4.2 Attitude And Translation Control Assembly (ATCA) - RCA

Negotiations with RCA were completed in the early part of April with program go-ahead given on April 29. RCA submitted a Program Plan for the ATCA, which was reviewed and rejected by reliability. Comments to this Program Plan are contained in LMO-550-338. Presently, there is no progress to report except for a request by RCA to use analog integrated circuits. RCA's request is based on the fact that integrated circuitry will decrease power and weight, and increase reliability. An evaluation of their proposed circuits is now in progress. The entire subject of analog integrated circuits is being investigated at this writing and will be reported in the next Quarterly Report.

5.2.4.3 Gimbal Drive Actuator (GDA) - AiResearch

Proposals for the GDA, received from Kearfott, Lear Siegler, AiResearch and Nash Controls, were reviewed and evaluated by Reliability. The overall engineering evaluation resulted in Garrett AiResearch being selected as vendor. Latest reliability requirements were submitted to the subsystem engineer for incorporation into the specification during negotiations which are scheduled to start early next quarter.

5.2.4.4 Attitude Controller Assembly (ACA)

The simplified Design Criteria and Reliability Assurance requirements were submitted for incorporation into the ACA specification. An amendment has been written to the Reliability Assurance and Qualification Tests and following review and sign-off the specification and vendor requirements will be submitted with the ITQ.

5.2.4.5 Descent Engine Control Assembly (DECA)

The proposal for the DECA from RCA, is scheduled to be received during the next reporting period.

5.2.4.6 Attitude Reference Assembly (ARA)

Engineering evaluation of the ARA proposals was completed and vendor selection is now awaiting NASA approval.

5.2.4.7 Abort Programmer Assembly (APA)

The procurement documents for the APA have been completed, but have not yet been released for quote.

5.2.4.8 Translation Controller Assembly (TCA)

The TCA specification contains the same simplified Design Criteria and Reliability Assurance requirements as the ACA. During this quarter the specification was released for engineering review and subsequently signed-off.

5.2.4.9 In-Flight Monitor Assembly (IFMA)

Procurement documents for the IFMA are in the preliminary stages of preparation and have not yet been released for engineering review.

5.2.5 Environmental Control Subsystem (ECS)

5.2.5.1 GAEC ECS Section Feasibility Tests

Design feasibility tests plans have been prepared for simulating the Heat Transport, Water Management and Oxygen Supply Sections. These tests, which will simulate section hardware and configuration layout, are to be conducted for the purpose of providing preliminary data on pressure drops, mass flow characteristics, temperature effects and interaction effects between these parameters.

5.2.5.2 ECS Components And Assemblies - Hamilton Standard (HSD)

LSP-330-23, incorporating the Reliability Boundary Conditions in accordance with the revised reliability assurance inputs to vendor specifications (reference LPL-550-1A) was released to HSD. Technical assistance by Reliability Assurance personnel has been provided to HSD for the purpose of scheduling the tests and facility usage to meet the validated Grumman test logic based on the delivery schedule in compliance with the Shea Study.

The design and pre-development phase of operations at HSD is phasing out with subsystem components being released for fabrication and corresponding development test plans being prepared and submitted for Grumman approval.

5.2.5.3 Partial Pressure Carbon Dioxide Sensor - Perkin - Elmer

Perkin - Elmer's contract with MSC was reviewed to ascertain whether the presently scheduled quality assurance provisions adequately cover the Grumman Reliability Assurance requirements. Preliminary comments were telephoned to MSC which subsequently amended the contract with Perkin - Elmer to include additional testing and stress-to-failure tests requested by Grumman. Additional recommendations concerning the Perkin - Elmer test program are under preparation and will be forwarded to MSC.

5.2.6 Electrical Power Subsystem (EPS)

5.2.6.1 Power Generation Section (PGS)

5.2.6.1.1 Fuel Cell Assembly (FCA) - Pratt & Whitney Aircraft (PWA)

Preliminary discussions were held with PWA in defining the revised Reliability Assurance requirements contained in LVC-391-002. Follow up coordination meetings are scheduled to further define, in detail, the technical aspects of the Reliability Assurance tests, in addition to facility availability and capability.

Design feasibility tests at PWA continued at an increased rate during this quarter and are summarized in Table 5.1

5.2.6.1.2 Cryogenic Hydrogen And Oxygen Storage And Supply Tank Assemblies - AiResearch

A coordination meeting at GAEC was held with AiResearch to disucss technical and scheduling aspects of the Reliability Assurance requirements. The results were reflected in the AiResearch Program Plan SS-3090 and will be further defined in the forthcoming General Test Plan.

5.2.6.1.3 Cryogenic Reactant Supply Components

Proposals were received for the following components and evaluated for their compliance with the Reliability Assurance requirements of the respective specifications.

1. Interstage Quick Disconnect
2. Latching Solenoid Valve
3. Relief Valve
4. Check Valve

5.2.6.2 Power Distribution Section

5.2.6.2.1 General Purpose Inverter

Eight (8) Vendor Proposals were received and evaluated for compliance with the Reliability Assurance requirements of LSP-390-6. The results of the evaluation are detailed and tabulated in LMO-550-298, May 7, 1964. Final procurement procedure will commence upon receipt of direction by MSC.

5.2.6.2.2 Electrical Power Distribution Components

Procurement documentation on components has progressed, as indicated in Table 5.0.

TABLE 5.1

Subcontractor Test Summary

Fuel Cell Assembly-Pratt & Whitney Aircraft

Item	Test	Results
Reactor Subassembly (Multi-Cell Stacks)	Performance of 9 cell stack	Test terminated because of KOH leakage past seals.
	Performance of 15 cell stack	Numerous replacement of malfunctional cells. Major cause of shutdown due to O_2 tube plugging, followed in seriousness by KOH leakage at the flange weld.
Seals and Insulators	Performance and endurance	Polymerized benzine (pyrolon) insulator tested for 502 hours without short. This design probably will be incorporated as part of the single cell.
Single Cells	Performance and endurance	1. Previous O_2 electrode pressure sensitivity and low bubble pressure and H_2 poor performance and low bubble pressure not nearly as serious as before. Appears to have been solved through the use of sinters having a more uniform open course porosity and other manufacturing changes. 2. H_2 screen-sinter separation still continues to be a problem, though not as serious as before. 3. KOH leakage at various points still a problem.

TABLE 5.1 (continued)

Item	Test	Results
Reactor Subassembly (continued)		
Single Cells (continued)	Performance and endurance	4. O_2 electrode plugging is the major problem at present. Tests are underway to determine cause.
	Initial vibration tests on water filled cells	Satisfactory
Intercell Heater	Performance	Dielectric strength and resistance tests-satisfactory. Power densities out of spec. limits.
Shock Mounts	Sine vibration	Response to vibration excitation within spec. limits.
Nitrogen Manifold	(Al_2 O_2) insulator structural test.	Test initiated.
Reactant Control Subassembly		
Hydrogen Flow Control	Vibration, using hot, dry nitrogen with inputs to simulate valves produced through the shock mounts.	Pre-and post-test heater and over temperature switch calibrations compared favorably, but the metering schedule reflected a lean maximum flow shift in the order of 27 percent. Possibly test set-up procedure problem. Need to evaluate an O-ring squeeze problem.

TABLE 5.1 (continued)

Item	Test	Results
Reactant Control Subassembly (continued)		
Fuel Control Valves	Miscellaneous failures	
Micro-Switch	Performance	Failed in open position.
Inlet Tube	Vibration	Broke under vibration.
Connector Receptacle	Vibration	One pin had intermittent contact.
H_2 Shut-Off Valve, Solenoid	Performance	Failed to operate-short between the coils and both diodes burned out.
Pressure Transducer	Life test at 250°F	Output in error beyond spec. limits over most of pressure range.

TABLE 5.1 (continued)

Item	Test	Results
Reactant Control Subassembly (continued)		
Heater and Over-temperature Switch	As received tests on first vendor control	Both short-circuited. Terminal plate being re-designed.
ESS	Room temperature bread-board testing	Satisfactory
2 amp relay & 10 amp relay	High temperature and various loads between 100 and 250% (150% for 10 amp relay) rated load at various voltages	Satisfactory
Solenoid Valves	Room-temperature flow tests	15 to 30% over-limit "continuous purge" flow on three units. Solenoid vendor to take corrective action.
Pressure Regulator	Acceptance tests	No deviations
Pressure Transducers	Vibration, pressure cycling, thermal transients, resistance checked and overpressurization.	Satisfactory. One failure (see Flow Control valves miscellaneous failures)
Nitrogen Tank	Burst pressure (2nd tank)	Failed at a hydrostatically - applied pressure of 9700 psig. Well above proof.

5.2.6.2.2 Electrical Power Distribution Components (continued)

Vendor Proposals for Circular Connectors (3) have been received and evaluated as to their compliance with the Reliability Assurance requirements of Specification LSP-390-8.

5.2.7 Instrumentation

5.2.7.1 Pulse Code Modulation and Timing Electronic Assembly (PCM/TEA) Radiation, Inc.

The PCM/TEA is progressing in its design feasibility stage. The Thermal Feasibility Model Test Plan LPC-1480-2 and the Mechanical Feasibility Model Test Plan LPC-1480-1 have been reviewed and found to be acceptable. A Detail Test Report, LTR-1480-1, of the Exploratory Vibration Tests on the Mechanical Model was received during the past quarter. Comment on the tests will be reserved since the tests will be rerun with a redesigned simulated cold plate. No other test reports have been received to date.

5.2.7.2 Caution and Warning Electronic Assembly (C&WEA)

The C&WEA Design Specification and Vendor Requirement Documents were released during the past quarter and submitted for bids. Vendor proposals have been received and are currently under evaluation.

5.2.7.3 OBCE, SCEA and DSEA

The following Instrumentation specifications are under preparation and Reliability inputs have been submitted for inclusion: OBCE, SCEA, and DSEA.

5.2.8 Communication Subsystem

5.2.8.1 VHF Inflight Antennas (Grumman)

Concentrated efforts are being made in the Development Test Program to design a setup whereby the VHF antennas can be tested under Ultra High Vacuum conditions at full radiated power, a Reliability Assurance requirement. The purpose of this test is to obtain performance information under critical environmental conditions and to test for a failure

5.2.8.1 VHF Inflight Antennas (Grumman) (continued)

mode known as multipacting, a phenomenon characteristic of high power levels, enclosed areas, high vacuum and a comparatively long mean-free electron path (i.e., to produce secondary emission). With the selection of the microwave absorption material and completion of the design of the enclosure configuration (simulation of a free space condition) the above test will be implemented.

5.2.8.2 VHF Diplexer (Grumman)

Negotiations for the VHF Diplexer were completed during the week of May 18 with the Rantec Corporation. Agreements were reached to implement the Simplified Design Environmental Test Program that imposes much higher levels and ranges than the expected Prelaunch or Mission environments will be, See Chart I.

Condition	Approximate Prelaunch Mission Levels or Ranges	Simplified Test Level
Vibration		
Sinusoidal	± 5.0g 5 to 500 cps	20g 5 to 3000cps
Random	$0.0783g^2/cps$	$0.6g^2/cps$
Shock	15g	50g

CHART I

Included in the Reliability Assurance requirements is a 500 hour run test to check for degradation and drift of any of the electrical characteristics of the unit. This test will also reveal the degree of maintainability required for the VHF Diplexer.

5.2.8.3 Manual Coaxial RF Switches

The Simplified Design Environmental Criteria is being implemented for both the VHF and S-Band Coaxial Switches which have been incorporated in the Coaxial RF Switch Specification LSP-380-7A, dated June 3, 1964.

5.2.9 Radar

During this period RCA continued with the breadboard model designs of the Rendezvous Radar and Transponder and initiated the fabrication of hardware and procurement of parts for the first two Experimental Models. Early significant tests were the exposure of the High Power Multiplier chains subassemblies to elevated temperatures to investigate stability characteristics and check for any performance degradation. Special attention is being given to HP Multipliers as they are composed of critical Microwave Circuits and contain components of relatively unproven Reliability. (e.g., Varactor Diodes).

Toward the latter part of this period RCA was informed of the revised Reliability Assurance requirements as outlined in the Section 5.0 of the last Quarterly Report. Due to the evaluation and near institution of the Flight Crew Systems Division study, an evaluation to provide an additional capability for the Rendezvous Radar to measure, during ascent, altitude and velocity accurately in case of an abort condition, some delay was encountered in implementing the Reliability Assurance requirements. One significant change in the Reliability Boundary Tables was the shifting of the Landing Radar Electronics from the Ascent Stage to the Descent Stage requirements.

The Transponder Antenna Design Control Specification was released on April 17, 1964 containing the Simplified Environmental Design Criteria and the detailed Reliability Boundary test requirements.

5.2.10 Structures and Materials

5.2.10.1 Ascent Stage Propellant Tank

The selected vendor for the Ascent Stage Propellant Tank is Aerojet. During the negotiation phase the responsible reliability engineer assisted the Vehicle Design and Integration Group in, clarifying and delineating Aerojets development test rationale.

5.2.10.2 Descent Stage Propellant Tank

No Reliability Assurance tests were performed on the Descent Stage Propellant Tanks during this quarter. Reliability Assurance Group continued their survaillance by reviewing Allison's test plans for the forthcoming design feasibility test. A full listing of the test plans are presented in Table 5.0.

5.2.10.3 Electro Explosive Devices (EED)

Design Feasibility tests are in progress on pyrotechnic devices to be used on Separation Stage Devices and the landing Gear Uplock Devices. The primary objective of these tests is to supply information to be used in the preparation of procurement documentation.

During this reporting period, NAA procurement Specification MC 453-0009B, Electrical Hotwire Initiator, proposed as a common usage item, was reviewed to determine its compatibility with LEM requirements. This review is covered in LMO-550-327.

5.2.11 Crew Provisions

Crew Provisions activities during this quarter consisted mainly of monitoring the 6 volt versus 28 volt incandescant lamp test program. This test has the unique reliability Stress-to-Failure test concept in the plan. Breifly, sixteen groups of lamps (each group representing different type) will be subjected to a random vibration test at the anticipated mission level and duration. The lamps will then be subjected to further excitation at spectral density levels increased by 10% throughout the frequency spectrum for four minutes. This process, with spectral density levels increased incrementally by 10% will be continued until all the test specimens have failed. By utilizing this step stress process, the actual strength margin of the lamps will be determined. This information in turn will be used in the selection process.

All other activities during this quarter were minimal. During the forthcoming quarter it is anticipated that reliability plans for the testing of the control panels, support and restraint system, and lighting sections will be initiated.

5.2.12 Controls and Displays

During the past quarter, the Reliability Assurance and the Reliability Boundary Table inputs to the applicable design control specifications have been modified to conform to the new Structural Analysis requirements. However, the majority of equipment specifications are not released for competitive bidding as of this date. A listing of modified specifications as well as those released for Vendor Negotiations is presented in Table 5.0.

5.2.13 Ground Support Equipment - GSE

The Reliability test effort for GSE was broadened in scope as the result of CCA's 29 and 51.

Various types of GSE have been categorized in accordance with their intended use and criticality as shown in Para. 6.2. The test program for GSE based on these categories has been initiated and equipment specifications are being reviewed accordingly. The list of documents reviewed during the past quarter is presented in Table 5.0

5.3 System Testing

The System Test Program planning has been revised as follows:

Name	Vehicle Name	Test Location
LTA-1	Integrated System (House Spacecraft)	GAEC
LTA-2	Dynamic Test	MSFC
LTA-3	Structural Test	GAEC
LTA-4	Environmental Development	GAEC
LTA-5	Propulsion & Combined Systems	WSMR
LTA-6	CSM/LEM Compatibility	NAA
LTA-7	Environmental Demonstration	MSC
LTA-8	CSM/LEM Environment & Compatibility	MSC
LTA-9	Propulsion & Combined Systems	WSMR
LTA-10	S-IVB Adapter/LEM Model & Separation	NAA

The Reliability Test Requirements are being prepared for the individual LTA Test Plans. These requirements will be translated into test objectives for particular test runs on LTA-1, LTA-4, LTA-5, LTA-7 and LTA-8. The object of the Reliability Test Requirements is to cover areas of test missed in the subsystem inputs to the test planning. The reliability effort to date has been mainly directed to the LTA-5 WSMR Test Plan.

5.4 Flight Development Program

During the quarterly reporting period the Apollo Spacecraft Development Test Plan (ASDTP) has been updated to define the ASDTP for the purpose of building flight development mission requirements. These requirements will be the basis of developing a document for MSC to control the Apollo development program. This document will contain LEM and FTA flight test mission planning assignments and definitions of each LEM mission. This test plan will be monitored to insure the availability of data to support the estimation of the numerical reliability of each subsystem.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
LEM RELIABILITY COMPUTER PROGRAM
TEST IDENTIFICATION TRANSMITTAL SHEET

DATE: ____________________

PREPARED BY: ____________________ EXT: __________

NUMBER 1 CARD

CODES	PART NUMBER	PART NAME	TEST PLAN NUMBER	S/M	VEN CDS	ASSO FAIL REPTS	NC	SEQUENCING
1 7								
1–6	7–26	27–46	47–66	67	68–69	70–71	72	73–80

NUMBER 2 CARD

CODES	TEST REPORT NUMBER	REPORT DATE YR / MO / DAY	TYPE TEST	TEST ENVIRONMENT	TEST FACILITY		
2 7							
1–6	7–26	27–32	33–37	38–57	58–62		

SUBSYSTEM CODE (THREE COLUMNS PER SUBSYSTEM)

CODES																					
3 7																					
1–6	7–9	10–12	13–15	16–18	19–21	22–24	25–27	28–30	31–33	34–36	37–39	40–42	43–45	46–48	49–51	52–54	55–57	58–60	61–63	64–66	67–69

70–72	

VENDOR CARD

CODES	VENDOR NAME	VENDOR PART NAME	SN CARDS	DATE PLANNED FROM YR / MO / DAY	DATE PLANNED TO YR / MO / DAY	DATE ACTUAL FROM YR / MO / DAY	DATE ACTUAL TO YR / MO / DAY	S		
4 7										
1–6	7–11	12–31	32–33	34–39	40–45	46–51	52–57	58		

SERIAL NUMBER CARD (SEVEN COLUMNS PER SERIAL NUMBER)

CODES										
5 7										
1–6	7–13	14–20	21–27	28–34	35–41	42–48	49–55	56–62	63–69	70

FAILURE REPORT CARD (10 COLUMNS PER FAILURE REPORT NUMBER)

CODES								
6 7								
1–6	7–16	17–26	27–36	37–46	47–56	57–66	67–72	73–80

NARRATIVE CARDS

CODES			
7 7			
7 7	7	72	73–80
7 7	7	72	73–80
7 7	7	72	73–80

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40

41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

CODING INSTRUCTIONS

1. S M — Multiple Subsystem Indicator, use S or M
2. VEN CDS — Number of Vendor Cards to be read
3. Asso. Fail Repts. — Indicate number of Failure Report Cards
4. Test I.D. Narrative — Max. — Four Cards
5. NC — Number of Narrative Cards to be read
6. SN Cards — Number of Serial No. Cards for this vendor
7. S — Test Status Indicator
   P — Planned
   I — In Progress
   C — Completed
8. Column 1 — Card Number
9. Column 3 — Test Identification
10. Column 5 — Transaction Codes:
    1 — Addition
    2 — Deletion
    5 — Change
11. Alphabetical characters are written as follows: A B C D E F G H I J K L M N Ø P Q R S T U V W X Y Z
12. Numerical characters are written as follows: 1 2 3 4 5 6 7 8 9 0
13. Write clearly so that a minimum of deciphering is required at keypunching and verifying time.

ENG 375 5-64

6.0 RELIABILITY SUPPORT ENGINEERING

6.1 Maintainability

The Maintainability effort for this quarter consisted of:

1. Development of a technique to quantify Reliability during the prelaunch phase of operations (LEM Maintainability Analysis).
2. Review of specifications, vendor requirements, and vendor proposals.
3. Monitoring vendor maintainability efforts through review of Monthly Progress Reports and attendance at vendor/GAEC Maintainability Review Meetings.
4. Participation in the Prelaunch Checkout Meetings at AMR.
5. Participation in GAEC/MIT G and N work group.

The LEM Maintainability Analysis is the technique developed to quantify Reliability during the prelaunch phase of operations. The analysis utilizes a Reliability Analysis Form, a Maintainability Requirements and Task Analysis Form, and a curve plotting Unreliability (Q, 1-R) versus time of LEM processing events. For each scheduled event an estimate is made of the unscheduled events that may take place as a result of the scheduled event. The failure modes of each "Replaceable Equipment" are assessed and the planned tests and checkouts are analyzed to determine the contribution of each failure mode to Unreliability during the Prelaunch Checkout phase of operations. A test which validates that a mode of failure has not taken place reduces the Unreliability of that mode to zero for that instant of time.

6.1.1 Propulsion Subsystem

In response to a GAEC request, Rocketdyne prepared an initial "Failure Mode and Effect Maintainability Analysis." This was presented at a Rocketdyne/GAEC Maintainability meeting at Bethpage. The Analysis also was published as part of Rocketdyne's Monthly Progress Report R-5205-12. This analysis covers the 180 day prelaunch period, and is useful to GAEC in the preparation of the LEM Maintainability Analysis.

6.1.1 Propulsion Subsystem (continued)

The Preliminary LEM Maintainability Analysis has been completed for the Rocketdyne Descent Engine and will be published shortly.

The prelaunch reliability (operational readiness) goal for the Descent engine was established as 0.99991, one order of magnitude greater than the mission success goal.

The preliminary analysis consisted of only four (4) items on the engine. It was determined that these items represent approximately 70 per cent of the Unreliability of the engine during the prelaunch period.

The analysis indicates that the Operational Readiness for these four (4) items is .97949. These results are considered significant enough to justify changes to the sequence and scope of the prelaunch checkout plan and to recommend accessibility to the descent engine at the Launch Pad to allow for testing and replacement of critical items. Incorporation of these changes to Prelaunch Checkout Plan and to design, in addition to updating of the maintainability analysis, will be the major effort expected during the next quarter reporting period on the Rocketdyne Engine.

The Maintainability Analysis for the STL Descent Engine is in progress. At a recent STL/GAEC Maintainability Meeting, STL was informed that it would be desirable to be able to replace failed items on an installed engine, rather than replace the engine during the prelaunch phase of operations. The following criteria was suggested to determine the practicality of replacement of assemblies:

1. Significant probability of failure.
2. Ability to detect all modes of failure.
3. Ability to isolate failure item.
4. Accessibility for removal and replacement.
5. Feasible revalidation requirements.
6. No hot firing requirements.

Using the above criteria as screens, STL was requested to review their engine design and recommend items which should be made replaceable.

6.1.2 Reaction Control Subsystem

The Maintainability Analysis for the Reaction Control Subsystem is in progress. Documents utilized for this analysis include the LEM Prelaunch Checkout Plan (LPL-610-3), Basic LEM Measurements List (LED-360-7), LEM Maintenance Plan (LPL-635-1A), Functional Requirements for LEM Subsystem Controls and Displays (LED-480-1B), and other vendor and GAEC publications.

A Logistic Support meeting between The Marquardt Corporation and GAEC personnel was held at Bethpage. Problems regarding RCS maintainability were discussed: specifically, the capability for replacing individual components without replacing major assemblies. For instance, Maintainability expressed the need for individual replaceability of filters, orifices, and thrust chamber assemblies, rather than the replacement of a complete cluster assembly.

6.1.3 Communications Subsystem

A preliminary study of the Communications Subsystem was performed in order to establish the lowest replaceable unit within the subsystem. This study was made to determine the level of maintainability and to present the results to the LEM Communications Subsystems Group for consideration in the design of the communications equipment.

The Maintainability concepts followed for this study are as follows:

1. After the equipment has been installed on the LEM, malfunctions will be isolated to an Electronic Replaceable Assembly (ERA) and to the lowest replaceable unit if performance, weight, and/or reliability are not significantly effected. When a malfunction has been detected, the ERA will be removed from the LEM and sent to the bench for further fault isolation.

   Meanwhile another qualified ERA will be mechanically but not electrically connected in the LEM. Power will not be applied to the replacement ERA until it has been determined that the detected malfunction has not been induced from a source external to the subject ERA.

6.1.3 Communications Subsystem (continued)

2. Prior to integration of new equipment into the LEM and/or while a failed ERA is on the bench, malfunctions will be isolated to the lowest replaceable unit and if possible to a component level.

3. A repair is considered to have been made after the following steps have been completed:

   a. The failure has been isolated to a replaceable unit within the ERA.

   b. The malfunctioning replaceable unit has been removed from the ERA and a qualified spare (replaceable unit) has been installed at the vendor's facility or at GAEC.

   c. The ERA has been functionally tested in compliance with acceptance test procedures.

The study also presents suggestions for circuit layout that would permit fault isolation to a level lower than the replaceable unit. Fault isolation to a replaceable unit is not to preclude the capability to perform more extensive fault isolation to the component or piece part level at AMR and/or GAEC and/or the vendor's facility.

During this reporting period, coordination meetings were held with RCA to discuss:

1. Details of the usage of the GSE and in-flight connectors. The general ground rule for this discussion was that there would be no duplicate information on the connectors (in accordance with the interpretation of the requirements for flight measurements and the GSE guide lines in the specifications (Reference: LMO-550-323).

2. Packaging

   a. Communications

      The RCA vendor proposes using a wire wrapped jumper technique instead of the split pin wire wrap for internal subassembly connections. Exceptions were taken to this technique because of added weight (additional wire required) and high probability of induced failures due to jumper wire chaffing under vibration. Wire chaffing could result in an in-flight failure and/or unscheduled maintenance during checkout.

6.1.3 Communications Subsystem (continued)

b. Radar

The RCA vendor proposed using a skewered sequential packaging approach. Exception were taken to this approach because:

(1) Other replaceable subassemblies (cards) must be disturbed while removing a failure subassembly.

(2) EMI gasketing would be disturbed.

(3) When a skewer is removed for card maintenance or fault isolation, undue stress would be placed on wire wrap connections of other subassemblies or cards.

(4) Special instructions and tools may be required to prevent overstressing when the skewer is tightened during assembly or reassembly.

6.1.4 Flight Control Subsystem

Preliminary efforts have begun on the method and concepts to be used in conducting a LEM Maintainability Analysis on the Flight Control Subsystem. As support information to the analysis a familiarization study of the flight hardware, ground support equipment capability, Prelaunch Checkout Plan (LPL-610-3) and RCA Task 12 is being accomplished.

Maintainability was represented at the RCS Checkout Working Group where the flight control portion of the Prelaunch Checkout Plan, LPL-610-3, was revised to be consistent with current checkout criteria and with the general philosophy of end-to-end test technique. The Group effort also included the preparation of a FCS integrated test. Maintainability's specific input to this Group was to ascertain, within current limitations, that the proposed tests are conducted at times which ensure that the operational readiness goal of the subsystem is met at launch.

Maintainability has also been represented at the GAEC/MIT G and N Checkout Working Group. The scope of the Group is to:

a. Prepare G and N related checkout procedures for LTA's and LEM's.

b. Define facilities and GSE requirements to implement the test plans and procedures.

c. Initiate checkout requirements.

6.1.4 Flight Control Subsystem (continued)

To support the efforts of the Group, Maintainability is currently preparing a presentation to evaluate the merit of performing a system test during static firing of the ascent engine at AMR.

6.1.5 Environmental Control Subsystem

The LEM Maintainability Analysis for the Atmospheric Revitalization Section of the Environmental Control Subsystem is in process. Inputs to the analysis are the Hamilton Standard Design and Test Specifications, Failure Mode and Effect Analysis, and the GAEC Prelaunch Checkout Plan (LPL-610-3).

The maintainability of the Oxygen Module of the Atmospheric Revitalization Section was analyzed. As a result, suggestions were made to relocate several valves into a more logical arrangement. The relocation of these valves will also enhance maintainability from an accessibility standpoint.

6.2 Ground Support Equipment

6.2.1 Summary and Discussion

6.2.1.1 Summary

The Reliability effort on LEM GSE during the past quarter has been concentrated in the following areas:

a. Evolution of a reliability program for Ground Support Equipment commencing with criticality classifications.

b. Establish Specification and Vendor Requirement (VR) standard formats and review of various GSE documents for reliability and maintainability requirements.

c. Review of common-usage GSE reliability requirements.

d. Review of Failure Mode and Effect Analysis (FMEA) techniques for LEM GSE.

e. Evaluation of vendor proposals.

6.2.1.2 Discussion

a. A Reliability program specifying requirements for all Ground Support Equipment is now a contractual requirement. To facilitate implementation of this program, LEM Reliability has established LEM GSE reliability criticality classifications, Table 6.2.1 which is being used to establish the depth of reliability effort on all Ground Support Equipment.

The extent of reliability program tasks to be performed for each criticality classification has initially been established and outlined during this report period in Table 6.2.2.

A review of current LEM GSE end item equipment lists, References (c) and (d), was performed and the equipment was grouped according to criticality classification to determine the quantity of items in each category. The following is a synopsis of this review:

Criticality Classification	Quantity Of GSE Items
MEE	62
MSE	101
MTE	29
MD/TE	185
TOTAL	377

b. To facilitate the reliability review of all LEM GSE Procurement Data Packages, standard formats of LEM GSE reliability and maintainability requirements were established to be incorporated in Design Control Specification and Vendor Requirement documents. These formats were released as enclosures to Reference (a).

When determined that it is not necessary to impose specific reliability requirements for a GSE item, a memorandum is prepared and submitted justifying the waiver of reliability requirements.

c. During this reporting period, various LEM GSE documents were reviewed for reliability and maintainability requirements. The status is shown in Table 6.2.3.

6.2.1.2 Discussion (continued)

d. The common-usage GSE items (29) comprise roughly 50 per cent of the equipments in the Mission Essential category. Discussions are in progress between NAA GSE and GAEC Reliability personnel to come up with a workable reliability program plan for handling the common-usage items. The main purpose of this plan will be to assure NASA of the conformance of these GSE items to LEM reliability/maintainability requirements.

e. Effort was also expended during this report period on a Failure Mode and Effect Analysis procedure for all GSE items. A comparison was made between the NAA and GAEC formats. The reason for this was twofold:

   1. Since some (31) items of GSE will be common-usage equipments, the NAA form was reviewed for compatibility.

   2. The existing GAEC form did not lend itself readily to the analysis of GSE.

   The end result of this comparison will be to use a "hybrid" form combining the best features of the NAA and GAEC forms.

   The FMEA will be done initially on a systems basis for MEE to determine the first order effects of a GSE failure on the primary GSE system, related GSE, and the LEM spacecraft and/or checkout or servicing function. It will also be a part of this analysis to investigate alternate methods of obtaining test or checkout data assuming a failure in the primary system

   Parts of the FMEA may be done in conjunction with the Maintainability Analysis. The accessibility and repairability of the GSE will be a prime consideration in determining the effect of a failure on the checkout sequence and any launch/hold decisions. Malfunction detection capabilities of the GSE system will be examined to establish whether a given malfunction can be detected, isolated, and corrected within a given time span.

   The following GSE items have undergone a preliminary FMEA:
   a. 410-92210, PCM Carry-on
   b. 410-92210 through -92214, Signal Conditioners
   c. 410-92230, Data Interleaver

6.2.1.2 Discussion (continued)

f. Vendor proposals were reviewed on the LEM Mission Simulator (440-43100), Supercritical LO_2 Development Bench (430-8120), and Supercritical LH_2 Development Bench (430-8130) for reliability/maintainability adequacy.

The anticipated effort for the next quarter will include the following tasks:

a. Attendance at common-usage design reviews.

b. Continuation of specification review effort.

c. Perform system FMEA on mission-essential GSE.

d. Continuation of proposal evaluation, vendor negotiations and surveillance.

e. Develop availability requirements for launch-associated GSE including apportionment ground rules.

6.2.2 General Functional Description

6.2.2.1 ACE-S/C

The ACE-S/C Functional Block Diagram shown as Figure 6.2.1 of Reference (b) remains virtually unchanged with the exception of the part numbers (which now reflect the common-usage designation). No block diagram is included in this report because of this minor change. The reliability block diagram of Reference (b) also remains unchanged.

6.2.2.2 Fluids Support Equipment

Functional block diagrams for the four (4) major groupings of Fluids Support Equipment were not available for inclusion in this report. It is, however, planned to include them in the next status report.

6.2.3 References

a. LMO-550-294, GSE Reliability Program

b. LPR-550-5, Fifth Quarterly Reliability Status Report

c. LED-400-9, GSE End Item Implementation Plan

d. LED-400-11, STE End Item Implementation Plan

TABLE 6.2.1

LEM RELIABILITY GSE CRITICALITY CLASSIFICATIONS

PRIMARY CLASSIFICATION		GENERAL LOCATION OF EQUIPMENT	EQUIPMENT
MEE	Mission Essential Equipment (I&II) GSE used as part of the launch complex; specifically that equipment, if failure occurred, would result in a personnel hazard, spacecraft failure, loss of equipment or causing long lead repair and launch delay.	AMR- Carry-on, Launch Umbilical Tower, Mobile Arming Tower, Ground Station, Launch Area	ACE S/C, ACE Support, Service Equipment (Fluids), Handling Equipment STU
MSE	Mission Support Equipment GSE used as backup to the launch complex for repair, checkout and maintenance; specifically that equipment, if failure occurred, would not result in unsafe conditions, long lead repair or launch delay.	AMR, Vertical Ass'y Building, Operations and Checkout, Remote Test Areas	BTME, STE, Service Equipment (Fluids), Handling Equipment
MTE	Mission Test Equipment GSE used for testing and checkout of deliverable equipment; if a failure occurred would not have a direct effect on the mission launch.	GAEC, WSMR, MSC, NAA, HSD and other vendor facilities	HSTE, BTME, STE, Service Equipment (Fluids), Handling Equipment
MD/TE	Mission Development/Training Eqpt. GSE used for testing and checkout of non-deliverable equipment or training purposes only; specifically that equipment having no contact with final equipment.	GAEC, and other vendor facilities	DTE, LMS

NOTE: The GSE Primary Criticality Classification will govern the Design Control Specification Reliability Requirements.

TABLE 6.2.2

RELIABILITY TASK REQUIREMENTS

RELIABILITY TASKS	CRITICALITY CLASSIFICATION			
	MEE	MSE	MTE	MD/TE
Reliability/Maintainability Assurance Plan	X	X		
*Reliability Assurance Detail Plan	X	X		
Reliability Estimate	X	X	X	
Parts Application and Standardization	X	X	X	X
Reliability Data List	X	X		
Configuration and Circuit Analysis	X			
Failure Effect Analysis	X	X	X	
*Failure Mode Prediction Analysis	X	X		
Failure Reports	X	X	X	X
Failure Analysis	X	X	X	X
Maintainability Analysis	X	X		
Reliability Monitoring of Vendors	X	X	X	X

*Only In Special Cases

Note: Individual requirements of each task are reduced in complexity as the criticality classification is reduced.

TABLE 6.2.3

STATUS OF LEM GSE DOCUMENTS

Criticality Class	Part Number	Item Name	LSP Review	LSP Sign-Off	LVR Review	LVR Sign-Off
MEE	430-54200	Transfer Unit, Gaseous Oxygen	X			
	430-54400	Test Unit Assembly, Cabin Leakage	X	X	X	
	430-54600	Freon Supply Unit	X		X	
	430-54700	Trim Control Unit Assembly, Water/Glycol	X	X	X	
	430-62180	Cart, Checkout, Reaction Control System	X			
	430-64420	Loading Control Assembly, Propellant	X			
	430-82720	Leak Detector Assembly, Mass Spectrometer, Helium or Hydrogen	X	X		
MSE	430-52120	Stand Assembly, Components Test, Gaseous Oxygen	X	X	X	X
	430-52160	Test Stand, Components, Water	X	X	X	X
	430-52210	Stand Assembly, Components Test, Water/ Glycol	X	X	X	X
	430-62100A	Test Stand, Helium Components, High Pres- sure	X			
MTE	400-12040A	Potentiometric Recorder and Indicator Components	X	X	X	
	420-63320	Force Measurement System	X			
	420-63840A	Actuation Subsystem, Static Firing Test Stand	X	X		

TABLE 6.2.3

STATUS OF LEM GSE DOCUMENTS

(continued)

Criticality Class	Part Number	Item Name	LSP Review	LSP Sign-Off	LVR Review	LVR Sign-Off
MD/TE	410-3138	Simulator Panel, Reaction Jet Solenoid	X	N/A	N/A	N/A
	410-3825	Signal Generating Equipment, Radar (Landing Radar and Rendezvous Radar)	X			
	410-7500A	Pulse Code Modulation and Timing Assembly, Development Test Station For	X			
	410-7600	Caution and Warning Electronics Assembly, Development Test Equipment For	X			
	430-5500	Internal Environmental Simulator	X	X		
	430-6320	Stand, Substitute, Fuel Storage and Transfer	X	X		
	430-6330	Stand, Substitute, Oxidizer Storage and Transfer	X	X		
	430-8120	Supercritical and Liquid Oxygen Development Bench Assembly	X	X	X	X
	430-8130	Supercritical and Liquid Hydrogen Development Bench Assembly	X	X	X	X
	430-8140A	Fuel Cell Test Bench Assembly, Development Gaseous	X	X		
	430-8170	Mass Spectrometer Leak Detector Assembly, Helium or Hydrogen	X	X		
	410-12000*	Electronic Equipment, LEM GSE, General Specification For	X			
	420-13000*	Handling and Transportation Equipment, LEM and Ground Support, General Spec. For	X			
	430-14000*	Ground Support Equipment, LEM Fluid Systems, General Specification For	X			
	430-18001**	GSE Fluid Distribution System Piping Criteria Specification	X			

* LSP - LEM Specification

** LIS - LEM Interface Specification

7 PARTS CONTROL AND EVALUATION

7.1 Acceptable Parts List

Preliminary revisions of the Acceptable Parts List and Application Guide, LED-550-25, including revised deratings for all transistors and semiconductor diodes, have been completed.

A preliminary Acceptable Parts List for Ground Support Equipment/Special Test Equipment (LED-550-32) is being readied for distribution.

7.2 Parts Procurement Specifications

Preliminary revisions of General (LSP) and Detailed (LSC) procurement specifications for transistors and semiconductor diodes for the LEM vehicle have been prepared. These specifications are intended to supplement the MIL specifications with screening requirements and with test levels and procedures more nearly representative of anticipated lunar environments. Present plans call for providing the subcontractors with these specifications for their use as guides in the preparation of their parts procurement specifications.

7.3 Parts Application and Liaison Activities

Considerable quantities of Type I documentation have been reviewed, including reliability data lists, procurement specifications, and requests for approval of non-preferred parts. Primarily, these have been submitted by subcontractors such as RCA, Radiation, Inc., Space Technology Laboratories, Bell Aerosystems Co., Rocketdyne, Kearfott, Elgin National Watch Co., and Motorola. Routine review was conducted during this quarter on program plans, status reports (monthly and quarterly), failure reports and parts qualification programs from the subcontractors.

7.4 Anticipated Effort for the Next Quarter

Work will continue on supplementing and revising the Acceptable Parts List and Application Guide for the LEM vehicle and also for Ground Support Equipment/Special Test Equipment.

7.4 Anticipated Effort for the Next Quarter (continued)

There will also be extensive review of (and comments on) subcontractor documentation. Other areas of activity will include a continuence of the preparation of parts procurement specifications and continued liaison with parts manufacturers to assure Grumman that the Parts Control Program is effective.

In addition, the question of the use of analog integrated circuits in LEM will be investigated for the purpose of making specific recommendations to MSC as to the conditions under which these parts might be accepted for LEM.

8.0 DOCUMENTATION RELEASED DURING THE REPORT PERIOD

8.1 Memorandums

Number	Date	Title
LMO-550-294	5-4-64	GSE Reliability Program
LMO-550-295	5-5-64	CANCELLED
LMO-550-296	5-5-64	PROPRIETARY
LMO-550-297	5-6-64	PROPRIETARY
LMO-550-233A (Revision)	5-7-64	Updated Alternate Paths For Determination Of Mission Success For The Guidance Function
LMO-550-298	5-7-64	PROPRIETARY
LMO-550-299	5-7-64	Reliability Analysis Of CSM Rescue Of LEM
LMO-550-300	5-8-64	PROPRIETARY
LMO-550-301	5-8-64	PROPRIETARY
LMO-550-302	5-8-64	Comments On Design Report No. 1, Dated 16 March 1964
LMO-550-303	5-12-64	PROPRIETARY
LMO-550-304	5-13-64	LEM Reliability PNGS/SCS Interface Configuration Analysis
LMO-550-305	5-18-64	ECS Quarterly Review Meeting At Hamilton Standard On 12 May 1964
LMO-550-306	5-19-64	PROPRIETARY
LMO-550-307	5-19-64	Trip Report - Apollo Checkout Panel Meeting No. 10(a), MSC, Houston, 7-8 May 1964
LMO-550-308	5-20-64	Reliability Review Of RCA Monthly Status Report

8.1 Memorandums (continued)

Number	Date	Title
LMO-550-309	5-20-64	Reliability Review Of RCA Rendezvous Radar Orbit Circularization Trade-Off Studies (U), LTM-B-3200-5, Dated 30 April 1964
LMO-550-310	5-27-64	Relialbility Review Of RCA Document "LEM System And Subsystem Reliability Data List, 26 March 1964"
LMO-550-311	5-27-64	Internal Environment Simulator, P.O. 2-24460, Reliability Effort
LMO-550-312	5-27-64	Reliability Comments To RCA Letter LCC-ASD-P-3200, 5100-470, Dated 14 May 1964
LMO-550-313	5-28-64	RCA Reliability Summary On The Third Quarterly Review, Marquardt Corporation, 14 And 15 May 1964
LMO-550-314	5-28-64	LEM Reliability - Controller Limit Switches Configuration Analysis
LMO-550-315	6-1-64	Reliability Comments On RCA Communications Subsystem Monthly Status Report Of 30 April 1964
LMO-550-316	6-3-64	Reliability Comments On NASA Provisioning Policy
LMO-550-317	6-4-64	LEM Reliability, Kearfott Division Of GPI, Rate Gyro Assembly - Program Plan, Evaluation Of
LMO-550-318	6-5-64	Reliability Reports For The Astrodata Signal Conditioner Specification
LMO-550-319	6-5-64	Minutes Of Meetings Of 26 May And 1 And 2 June 1964, Guidance And Control Alternate Paths
LMO-550-320	6-5-64	Reliability Comments On Proposed PDS Schemes

8.1 Memorandums (continued)

Number	Date	Title
LMO-550-321	6-9-64	Lecture For Corporate Failure Reporting
LMO-550-322	6-9-64	Reliability Comments On RCA Communications Packaging Study Of 11 May 1964
LMO-550-323	6-10-64	Minutes Of GAEC/RCA Meeting Concerning Maintainability/Reliability Requirements
LMO-550-324	6-9-64	LEM GSE Parts
LMO-550-325	6-13-64	Input To Performance Specification For The Microwave Switch Used In The X-Band Transponder
LMO-550-326	6-15-64	Review Of Airesearch Program Plan SS-3090, Dated 4 May 1964, Received 26 June 1964
LMO-550-327	6-16-64	Review Of NAA Procurement Specification MC-453-00093 As A Common Usage Source For LEM Pyrotechnic Devices
LMO-550-328	6-16-64	STL/GAEC Maintainability Conference
LMO-550-329	6-16-64	Reliability Review Of RCA Document LEM System And Subsystem Reliability Data List, Dated 15 May 1964
LMO-550-299A (Revision)	6-16-64	Reliability Analysis Of CSM Rescue Of LEM
LMO-550-330	6-17-64	Test Program Plans For The Communication Subsystem VHF In-Flight S-Band In-Flight And Lunar Stay Antennas
LMO-550-331	6-17-64	Reliability Of The Test Program Function On LEM 3 If The LGC And Tape Reader Are Implemented

8.1 Memorandums (continued)

Number	Date	Title
LMO-550-332	6-18-64	Response To RA TWX 4843, Dated 12 June 1964: Pertinent To LEM Instrumentation (PCMTEA) P.O. 2-18848-C
LMO-550-333	6-18-64	Trip Report To Hamilton Standard
LMO-550-334	6-18-64	Minutes Of Meeting - 11 June 1964 - Between HSD And GAEC Reliability Of ECS
LMO-550-335		CANCELLED
LMO-550-336	6-22-64	PROPRIETARY
LMO-550-337	6-22-64	Trip Report On Reliability Attendance
LMO-550-338	6-22-64	Reliability Evaluation Of RCA Program For ATCA, Dated 28 May 1964
LMO-550-339	6-22-64	Addition Of A "Communication Equipment Life" Paragraph To The Communication Subsystem Specification, LSP-380-2
LMO-550-340		CANCELLED
LMO-550-341	6-23-64	Allison Program Planning Documents EDR-3700, Dated 10 January 1964, And EDR-3700A, Dated 1 June 1964
LMO-550-342		CANCELLED
LMO-550-343	6-23-64	STL Preliminary Reliability Report, Dated 1 April 1964
LMO-550-344	6-24-64	LEM Relialbility Computer Program
LMO-550-345	6-26-64	Trip Report To NASA/MSC For Pyrotechnic Meeting Held On 2 And 3 June 1964

8.1 Memorandums (continued)

Number	Date	Title
LMO-550-346	6-26-64	Reliability Requirements For Development Fuel Cell Test Bench Assembly LSP-430-8140A
LMO-550-347	6-29-64	Breakdown Of The Communications Subsystem For Maintainability
LMO-550-348	6-30-64	Alternate Paths For The Guidance Function After Loss Of Two Fuel Cell Assemblies
LMO-550-349	7-1-64	STL/LEM Descent Engine Injector Assembly Reliability Assurance Detail Test Plan, STL Report 8438-6108-SU000, Dated 22 May 1964 - TYPE I DOCUMENT
LMO-550-350	7-7-64	Reliability Review Of RCA LEM Monthly Status Report, Dated 30 April 1964, LMR-(P)-3100-6, Radar Equipment
LMO-550-351	7-13-64	Requirements For The Development Of The Apollo Radiation Cooled Reaction Control Engine
LMO-550-352	7-13-64	PROPRIETARY
LMO-550-353	7-13-64	Comments On Support Manual Outline Tanks Positive Expulsion Propellant RCS BAC Model 8339
LMO-550-354	7-13-64	Reliability Control's Review Of The Acceptance Test Plan For The Descent Stage Propellants Flank
LMO-550-355	7-15-64	Mission Success Paths For Guidance And Control Function With Existing Configuration And Digital Auto Pilot Configuration
LMO-550-356	7-15-64	PROPRIETARY

8.1 Memorandums (continued)

Number	Date	Title
LMO-550-357	7-17-64	Meeting On LRCCP On 13 July 1964
LMO-550-358	7-17-64	Transfer Of D/S Engine Static Firing From AMR To WSMR Effect On Launch Q And Operational Readiness
LMO-550-359	7-20-64	Comments Re: STL Thrust Mount And Gimbal Assembly Reliability Assurance Test Plan No. 8438-6118-SU000, Dated 12 June 1964 - TYPE I DOCUMENT
LMO-550-360	7-20-64	Fuel Cell Assembly Study
LMO-550-361	7-21-64	Review Of The Seventh Monthly Status Report From RCA On Radars LMR-(P)-3100-7
LMO-550-362	7-21-64	Reliability Review Of Kearfott Monthly Report On RGA, Concerning Period 1 May Through 31 May 1964
LMO-550-363	7-21-64	Failure Reporting Requirements For LEM, Implementation Of
LMO-550-364	7-22-64	RCA Request For Non-Preferred Part Approval For Varactor Diodes And Transistors
LMO-550-365	7-22-64	Input To Performance Specification For The Waveguide Assemblies Used In The X-Band Transponder
LMO-550-366	7-22-64	Reliability Review Of RCA Second Quarterly Design Report LQR-(P)-3100-2, Dated 15 June 1964
LMO-550-367	7-22-64	Reliability Comments To The Kearfott Test Plan For The Engineering Portion Of Design Verification Tests

8.1 Memorandums (continued)

Number	Date	Title
LMO-550-368	7-22-64	Reliability Effort On LEM GSE
LMO-550-369	7-22-64	Comments Re: Bell Reliability Assurance Test Plan And Failure Mode Prediction Analysis, Report No. 8258-932004, Dated 15 June 1964 - TYPE I DOCUMENT
LMO-550-370	7-23-64	GAEC Reliability Comments On RCA First Communications Quarterly Report
LMO-550-371	7-24-64	Reliability Inputs To Performance Specifications And Vendor Request For The Waveguide Switch And Waveguide Assemblies, LVR/LSP-370-202 And -203
LMO-550-372	7-24-64	Fuel And Oxidizer Transfer Units (S14-002-008) Common Usage GSE Waiver Of Qualification For Conditioning System Subassembly
LMO-550-373	7-27-64	PROPRIETARY
LMO-550-374	7-28-64	Evaluation Of TMC Reliability Testing Program Plan
LMO-550-375	7-31-64	Comments Regarding STL Propellant Shut-Off Valve Assembly, Reliability Assurance Test Plan No. 8438-6120-SU000, Dated 19 June 1964

8.2 LED's (LEM Engineering Data)

LED-550-28	5-25-64	RCS Reliability Ground Rules And Estimates For Success Path Study [redacted]
LED-550-29	5-11-64	Micro-Meteoroid Study Weight-Reliability Trade-Off [redacted]
LED-550-30	5-15-64	Mission Success Path Study Of The Related Functions Of The Electrical Power And Environmental Control Subsystems
LED-550-31	6-19-64	LEM Mission Success Paths For Propulsion Subsystems
LED-550-32	6-26-64	Acceptable Parts For GSE/STE
LED-550-33	7-2-64	LEM Reliability Apportionment Technique
LED-550-34	7-24-64	Maintainability Analysis Prelaunch Operational Readiness Of The Fixed Injector Descent Engine